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Le bruit comme problème de santé publique

Noise as a Public Health Problem

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Volume 1 includes abstracts of the four main conferences and of 51 invited papers on the various effects of noise on people. It also includes the reflections of the European Community Commission (DG XI) and the World Health Organisation concerning, noise, together with 10 abstracts on the special workshop papers concerning control of damage to the ear and on sleep.

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PREFACE

This volume is the first in a series of three reporting the proceedings of the 6th International Congress on Noise as a Public Health Problem which was held in Nice, France, from the 5th to the 9th of July 1993.

Volume 1 includes abstracts of the four main conferences and of 51 invited papers on the various effects of noise on people. It also includes the reflections of the European Community Commission (DG XI) and the World Health Organisation concerning noise, together with 10 abstracts on the special workshop papers concerning control of damage to the ear and on sleep.

Volume 2 contains the 160 papers presented by participants during the Congress.

Volume 3, to be published at the end of 1993 or early in 1994, will include the texts of the main conferences and the invited papers, together with the speeches by the principal guests. A summary of all the papers presented during the 9 sessions will also be included in this volume in French and English.

A list of contents enabling identification of each author's texts will be included in volume 3.

These proceedings are published with financial help from the Institutions listed in the preceding pages and I would like to take this opportunity of thanking them for their participation.

I would also like to thank my colleagues - Patricia Champelovier, Nicole Teillac, Isabelle Vernet, Jacques Lambert and Michel Maurin - for their help in preparing this publication.

Michel Vallet
Research Director

PRÉFACE

Ce volume est le premier de la série de trois ouvrages destinés à rendre compte du 6ème Congrès International sur le bruit comme problème de santé publique qui s'est tenu à Nice du 5 au 9 juillet 1993.

Le volume 1 comprend les résumés des 4 conférences principales, des 51 communications invitées sur les différents effets du bruit sur l'homme. On trouve aussi les considérations de la Commission des Communautés Européennes (DG XI) et de l'Organisation Mondiale de la Santé en matière de bruit, ainsi que 10 résumés des communications aux ateliers spéciaux sur le contrôle des dommages à l'oreille et sur le sommeil.

Le volume 2 intègre plus de 160 communications présentées par les participants.

Le volume 3, qui sera publié fin 1993 ou début 1994, sera composé des textes des conférences et des communications invitées, ainsi que des interventions des personnalités. Les résumés en anglais et en français de chacune des 9 sessions seront aussi intégrés à ce volume.

Pour retrouver le texte d'un auteur il convient de se réferer à la table la plus complète que l'on trouvera au volume 3.

L'ensemble des actes est publié grâce à l'aide des organismes cités dans les pages précédentes et je remercie tous ceux qui ont décidé ces aides.

Je remercie aussi mes collègues Patricia Champelovier, Nicole Teillac, Isabelle Vernet, Jacques Lambert et Michel Maurin pour leur aide à la publication de ces actes.

Michel Vallet
Directeur de Recherche

TABLE OF CONTENTS-TABLE DES MATIERES

Opening Ceremony - Cérémonie d'ouverture

Vallet M
Noise research as a problem of public health
La recherche sur le bruit comme problème de santé publique 1

Muzet A
Introductory remarks 3

Perera P
European Communities noise policy in the light of the 5th environmental action programme 4

Bonnefoy X
Community noise
Le bruit d'ambiance 6

Namba S
Psychological approach to noise research for future needs 8

Ward W
Developments in noise-induced hearing loss during the last 25 years 10

Regulations and standards - Les réglementations sur le bruit
Invited papers - Communications invitées

Von Gierke HE
Noise regulations and standards : progress, experiences and challenges 12

Berry BF - Porter N
Standards for industrial environmental noise exposure : current UK research 13

Van Den Berg M
Noise and the art of maintenance 14

Vogel A
International aspects of noise standards compared to other environmental factors 15

Noise and communication - Bruit et communication
Invited papers - Communications invitées

Houtgast T
Noise and communication : general introduction 16

Lazarus H
Methods to predict and assess speech communication and signal recognition with regard to standardization 17

Abel SM
The effect of hearing protective devices on directional hearing in quiet and noisy surroundings 18

Smoorenburg GF
Hearing handicap assessment for speech perception in industrial noise based on pure tone audiometry 19

Edworthy J
Auditory warning design....20

Tohyama M
Modern techniques for improving speech intelligibility in noisy environments....21

Non-auditory physiological effects - Effets physiologiques non auditifs dus au bruit
Invited papers - Communications invitées

Schwarze S - Thompson SJ
Research on non-auditory physiological effects of noise since 1988 : review and perspectives....22

Babisch W - Elwood PC - Ising H
Road traffic noise and heart disease risk : results of the epidemiological studies in Caerphilly, Speedwell and Berlin..23

Stansfeld SA - Gallacher J - Babisch W - Elwood P
Road traffic noise, noise sensitivity and psychiatric disorder : preliminary prospective findings from the Caerphilly study....24

Zhao Y - Zhang S - Selvin S - Spear RC
A dose response relationship between cumulative noise exposure and hypertension among female textile workers without hearing protection....25

Ising H - Rebentisch E
Comparison of acute reactions and long-term extra-aural effects of occupational and environmental noise exposure....26

Noise and animal life - Le bruit et la vie animale
Invited papers - Communications invitées

Bowles AE - McClenaghan L - Francine JK - Wisely S - Golightly R - Kull R
Effects of aircraft noise on predator-prey ecology of the kit fox (vulpes macrotis) and its small mammal prey....27

Krausman PR - Wallace MC - De Youg DW - Weisenberger ME - Hayes CL
The effects of low-altitude aircraft on desert unglates....28

Murphy SM - White RG - Kugler BA
The effects of aircraft overflights on an Alaskan caribou herd....29

Stephan E
Behavioural patterns of domestic animals as induced by different qualities and quantities of aircraft noise....30

Kull RCJ
An overview of USAF studies on the effects of aircraft overflight noise on wild and domestic animals....31

Noise and combined agents - Le bruit et les agents combinés
Invited papers - Communications invitées

Manninen O
Synopsis of studies on combined effects....32

Saito K
Analysis of brain activities to the combination of noise and other environmental factors during mental and physical loads....33

Groll-Knapp E - Haider M - Trimmel M - Hörtnagl H
Changes in brain functions due to noise and its combination with brain affecting substances 34

Rentzsch M - Kullman G - Pascher G
Noise and vibration as indicators for using experience based knowledge 35

Influence of noise on performance and behaviour -
Influence du bruit sur les performances et le comportement
Invited papers - Communications invitées

Smith AP
Recent advances in the study of noise and human performance 36

Hygge S - Evans GW - Bullinger M
The Munich airport noise study : psychophysiological, cognitive, and quality of life effects on children 37

Jones DM - Macken B
Voice pollution : auditory distraction and cognition 38

Hellbrück J - Kilcher H
Effects on mental tasks caused by background sound recorded and presented via an artificial head system 39

Noise induced hearing loss - Le bruit et les pertes auditives
Invited papers - Communications invitées

Passchier-Vermeer W
Noise-induced hearing loss from daily occupational noise exposure ; extrapolations to other exposure patterns and other populations 40

Alberti PW
Efficacy of hearing conservation programs ; prediction of NIHL, remediation 41

Lutman ME - Davis AC - Spencer HS
Interpreting NIHL by comparison of noise exposed subjects with appropriate controls 42

Patterson JH - Mozo BT - Johnson DL
Actual effectiveness of hearing protection in high level impluse noise 43

Dancer A
Predictions of NIHL based on animal studies ; species differences and their implication 44

Pujol R
Recent advances in cochlear neurobiology and new concepts in acoustic trauma 45

Ward WD
Current exposure standards ; interaction of exposures ; critical exposures ; morphology of TTS and PTS 46

Night time noise sources and sleep disturbance, methodological issues and critical load -
Sources de bruit et troubles du sommeil, aspects méthodologiques et seuils critiques
Workshop - Atelier

Griefahn B
Models to determine critical loads for nocturnal noise 47

Ollerhead JB - Diamond ID
Social surveys of night-time effects of aircraft noise 48

Hume KI - Van F - Watson A
EEG-based responses to aircraft noise for subjects sleeping at home 49

Horne JA - Pankhurst FL - Reyner LA
A field study on the effects of aircraft noise on actimetrically and subjectively monitored sleep 50

Carter NL - Crawford G - Kelly D - Hunyor SN
Environmental noise during sleep and sympathetic arousal assessed by urinary catecholamines 51

Noise disturbed sleep - La perturbation du sommeil par le bruit
Invited papers - Communications invitées

Öhrström E
Research on noise and sleep : present state 52

Maschke C - Gruber J - Leiss R
The influence of night-flight noise on sleep : changes in sleep stages and increased catecholamine secretion 53

Nicolas A - Tassi P - Dewasnes G - Ehrhart J - Muzet A
Noise during daytime sleep : EEG disturbances in shift workers 54

Ollerhead JB - Jones C
Aircraft noise and sleep disturbance : a UK field study 55

Öhrström E
Effects of low levels from road traffic noise during night - A laboratory study on number of events, maximum noise levels and noise sensivity 56

Community response to noise - La réponse de la communauté au bruit
Invited papers - Communications invitées

De Jong RG
General developments in community response research 57

Fields JM
Theories and evidence on the effect of ambient noise on reactions to major noise sources 58

Buchta E
A review of the penalty for impulsive noise 59

Miedema HME
Response functions for environmental noise 60

Lambert J
The social impact of roise prevention and reduction measures 61

Central control of auditory system vulnerability to noise exposure - Contrôle central de vulnérabilité du système auditif soumis au bruit

Workshop - Atelier

Borg E
Acoustic reflex features and noise damage to the ear ... 62

Canlon B
Protection from noise-induced hearing loss by pre-exposure to noise ... 63

Henderson D - Subramaniam M - Attanasio G
Possible physiological changes underlying the noise-induced toughening effect ... 64

Puel JL
Cochlear efferents and acoustic trauma ... 65

Rajan R
Protective functions of the mammalian olivocochlear pathways ... 66

Regulations and standards - Les réglementations sur le bruit

Invited papers - Communications invitées

Gottlob D
Basic concepts of noise regulations in Germany as compared to European guidelines ... 67

Psichas K - Vogiatzis C
Regulations and standards against noise from road traffic and entertainment in urban areas of Greece ... 68

Dickinson P
Standards for protection of community health ... 69

Celma Celma J
Noise and traffic ... 70

Pietry Verdy MF
Original and specific regulation for compensation against unhealthy noise at E.D.F.-G.D.F. ... 71

Jansen G
Applied noise research and its effects on regulations and standards ... 72

Closing Ceremony - Cérémonie de clôture

Job RFS
Psychological factors in community reation to noise ... 73

Lamure CA
Technical aspects of noise immission reduction from land transport ... 75

Author index - Index des auteurs ... 79

NOISE RESEARCH AS A PROBLEM OF PUBLIC HEALTH

Michel Vallet
Congress Chairman

The goal of Noise Research is to extend knowledge about auditory and non-auditory phenomena and to influence noise abatement policies both in the context of public health, for example in the workplace or as a factor in the quality of life which also leads to the consideration of effects on health in the wider sense as defined by the World Health Organisation.

The team from the INRETS' Laboratoire Energie Nuisances, the Congress organisers, is more specifically dedicated to protecting people from noise generated by transportation. I was personally extremely happy to note that the on-going research undertaken for over 20 years has been able to provide the Civil Service with scientific data enabling decisions to be taken and the preparation of regulations.

This research effort has also ensured that Public Authorities are kept constantly aware of the exposure of people to noise. Noise is continually increasing despite noise abatement policies adopted by many Nations including, of course, members of the OECD. It is probably true that regulations do not go far enough to protect the environment, that they are not always applied to their fullest extent - particularly in the workplace - and that the conclusions of scientists as to the most suitable noise thresholds may appear more unrealistic than practical and do not often consider the costs involved. One result of this unambitious approach is that in Europe noise is becoming a major preoccupation of people in general. Noise continues to have a major impact on auditory and nervous systems and we are observing the appearance of specific forms of stress and psychosomatic disorders.

Workplace surveys carried out in France in 1978, 1984 and again in 1991 show that the main grievances are unchanged - standing for long periods, breathing dusts and being subjected to very loud and very high pitched noises.

However, the situation in schools was much improved by soundproofed facades and by reducing acoustic reverberation in classrooms and canteens.

At the end of 1992 the French Parliament passed a law on noise abatement with an ambitious but rather realistic objective which was to limit domestic exposure to noise to a Leq of 60 dB (A). This major decision by the Ministry for the Environment was backed by research which showed that the previous threshold of 65 dB (A), which only applied to roads, was not low enough and did not satisfy the population.

Findings showed that although the 65 dB (A) threshold eliminated most health risks it did not meet the WHO definition of well-being. The Swiss threshold goal of 55 dB (A) clearly aims to ensure comfort.

Quite obviously a single threshold value is not realistic for all places and all periods throughout the day. Very low daytime thresholds in urban sites are not realistic. Current research is examining ways in which to differentiate noise thresholds better adapted to the sites to be protected. In France work is proceeding for a proposal for a specific evening and night time acoustic index.

This congress is a means by which positive action and noise abatement approaches can be consolidated in countries in which such measures are already in force and to make other Nations aware that noise is truly a Public Health problem.

LA RECHERCHE SUR LE BRUIT COMME PROBLEME DE SANTE PUBLIQUE

La recherche en matière de bruit a pour finalité de faire avancer la connaissance sur les phénomènes auditifs et non auditifs et d'orienter les politiques de lutte contre le bruit, que celui-ci soit considéré comme un problème de santé publique, c'est bien le cas au travail, ou comme un élément du cadre et de la qualité de la vie, ce qui revient à considérer un impact sur la santé au sens large défini par l'Organisation Mondiale de la Santé.

Avec l'équipe du Laboratoire Energie Nuisances de l'INRETS, organisatrice de ce congrès et qui travaille à éviter l'intrusion du bruit des transports dans l'environnement des habitants, j'ai été heureux de constater que la continuité de la recherche depuis plus de 20 ans a permis de fournir à l'Administration des éléments scientifiques pour la prise de décisions et de réglementations.

Ensuite l'activité continue de recherche a contribué à maintenir l'attention des Pouvoirs Publics sur le problème de l'exposition des habitants au bruit, exposition dont l'ampleur continue de croître régulièrement, malgré les politiques de lutte contre le bruit adoptées dans de nombreux pays dont ceux de l'OCDE. Il est vraisemblable que les réglementations manquent d'ambition en matière d'environnement, qu'elles sont mal appliquées, notamment au travail, et que les conclusions des chercheurs en terme de seuil de bruit apparaissent à certains utopiques, surtout au regard des contraintes économiques. Un résultat de ce manque d'ambition est que le bruit, en Europe, focalise de plus en plus les préoccupations de la population. Le bruit continue, chez un nombre croissant de personnes, de solliciter le système auditif et le système nerveux, favorisant l'apparition d'un stress spécifique et de maladies psychosomatiques.

Au travail, rester longtemps debout, respirer des poussières, subir des bruits très forts ou très aigus restent en 1991, comme lors des enquêtes de 1978 et 1984 réalisées en France, les aspects les plus pénibles.

Cependant la situation dans les écoles a été très améliorée par les isolations de façade et par le traitement de la réverbération acoustique dans les salles de cours et les restaurants scolaires.

En France, à la fin de l'année 1992, le Parlement a voté une loi sur la protection contre le bruit avec un objectif ambitieux, mais non irréaliste, de limiter l'exposition des logements à un maximum de 60 dB (A) (en niveau énergétique équivalent de jour). Les travaux de recherche ont aidé à la prise de cette décision importante au Ministère de l'Environnement, en soulignant dans les résultats expérimentaux, que le seuil précédent de 65 dB (A) et appliqué seulement aux routes, n'était pas assez bas, et que une certaine insatisfaction demeurait parmi la population

Si ce seuil de 65 dB (A) évite la plupart des atteintes à la santé il ne procure pas encore le bien être évoqué dans la définition de la santé par l'OMS. La Suisse en proposant 55 dB (A) comme seuil de planification vise clairement un seuil de confort.

On peut considérer qu'une seule valeur seuil n'est pas réaliste pour tous les lieux et toutes les périodes de la journée. Des seuils trop bas pour la journée, en site urbain ne sont pas réalistes. L'orientation actuelle des recherches consiste à examiner l'intérêt de seuils de bruit différenciés et adaptés aux sites à protéger. Aussi en France on travaille sur une proposition d'indice acoustique spécifique de soirée et de nuit.

Le rôle de notre congrès, aujourd'hui, est de consolider les raisons d'action et orientations de lutte contre le bruit, dans les pays ou celle-ci est bien engagée et d'aider les autres pays à être vigilant sur le bruit comme problème de Santé Publique.

Michel Vallet
Président du Congrès

INTRODUCTORY REMARKS

MUZET Alain
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On behalf of the International Commission on Biological Effects of Noise let me welcome you on this first day of the 6th International Congress on Noise as a Public Health Problem. I would like to welcome our honored and distinguished guests and to welcome all of you the participants to this congress. Your presence here today and for the few days to come shows how important this meeting is.

The Commission wishes to thank specially those who have made this congress possible. Among them, the acoustical societies, the French Government and public research organizations, several organizations from different european countries as well as from the U.S.A. and Canada, the Commission of the European Communities and the World Health Organization and, of course, INRETS, Michel Vallet and his co-workers.

The program for this congress is organized around the nine international teams which constitute the Commission and define its interests. Each of these nine groups is composed of about twelve scientists who are experts in the field covered by the team. No more than two members in each team have the same nationality and this rule makes these groups truly international.

The main purpose of this meeting is to bring together scientists, industrial and governmental working people, as well as individuals and representatives of organizations and associations, to exchange their knowledge and interrogations and, in a word, to communicate.

Today many people, in and outside the cities, are exposed to the noise that transportation systems, factories and outdoor activities produce day and night. The adverse health effects of noise on man are still difficult to determine because of the interaction of noise with other environmental factors and because of those factors, identified or not, which tend to make people react in a different manner from each other. But after all, each of us is concerned with the protection against noise as we all contribute to its production.

We know that research cannot solve all the problems we are going to discuss in the next few days. But we know also that there is no better place to have these discussions between researchers and those who have to take and to apply the decisions. In order to reach this goal we need to obtain a critical and constructive cooperation of all the present bodies. An international meeting like this one is necessary to increase communication and exchange our experience. We should all profit from the knowledge that you bring with you and pass around. I wish this congress success in making this important goal possible.

EUROPEAN COMMUNITIES NOISE POLICY IN THE LIGHT OF THE 5TH ENVIRONMENTAL ACTION PROGRAMME

PERERA MANZANEDO Prudencio
Commission of the European Communities, DG XI B.3 (Urban Environment)
Rue de la Loi 200, B-1049 Brussels - Belgique

On behalf of the Commission of the European Communities and on my own behalf I was happy to accept the invitation of the organisation of the 6th International Congress on Noise as a Public Health Problem. I believe that the importance of this congress lies in its concentration on just this topic : Man and Noise. In the different sections all main effects of noise on man and his well-being are included, inter alia, noise and communication, non-auditory physiological effects induced by noise, noise and performance and behaviour, sleep disturbance by noise and noise and hearing loss.

In this conference of outstanding physicians and acousticians from all over the world you do not need me to remind you of these various significant impacts of noise. The fundamental issue which I am sure you would wish me to address is : how is the European Community going to promote policies to reduce this impact ?

The present noise policy of the European Communities has been primarily based on directives which deal with sound emissions of cars, trucks, aircraft, special types of construction plant and equipment, lawnmowers, etc. Valuable as they are it must however be admitted that these directives have been motivated only in past by environmental concerns, their essential role being in the harmonization of products norms required for the achievement of the Single Market. The Communities recently approved the 5th Environmental Action Programme, which was adopted by the Council on 1st February 1993, *it is foreseen that the Community will be seeking to further* contribute to noise abatement by reduction in permissible noise emission levels.

This 5th Environmental Action Programme has also broken new ground in the area of Community noise policy by introducing for the first time the question of Community set noise quality objectives, setting out the following targets up to the year 2000 in respect to Leq in dB(A) at night-time :

- exposure of the population to noise levels in excess of 65 should be phased out : at no point in time a level of 85 should be exceeded.
- proportion of population at present exposed to levels between 55-65 should not suffer any increase.
- proportion of population at present exposed to levels less than 55 should not suffer any increase above that level.

Although the setting of this initial set of objectives is important, they obviously do not represent a comprehensive noise criteria policy. If the Community is to develop such policy, we must build on these initial targets to the full range of noise situations and also review, on the basis of further considerations and research, the initial targets proposed.

In developing this work the Commission needs close cooperation with specialists, institutes and international organizations. Of particular value would be collaboration with the WHO who we know are very active in this field. At present the Commission is exploring such collaboration on the lines of our existing collaboration agreement on air quality issues.

The establishment of other objectives in the area of noise reduction will, I fell, be of fundamental importance in driving forward noise abatement policies throughout the Community. This is not to suggest that the Commission is seeking to extend its competence and role in the issue, but sees these criteria as aiding the establishment of objective targets for product noise limits by the Community as well as targets for the more local actions which are rightly within the competence of national and local governments.

The potential role of the European Environment Agency must not be underestimated. The establishment of monitoring programmes to check on the achievement of targets and the provision of good information to general public should not be underestimated as a force to increase the priority given at all levels to the implementation of meaningful action to reduce noise.

I wish the 6th International Congress on Noise as a Public Health Problem great success with clear-cut results, capable of being understood both by the general public and by decision-makers.

COMMUNITY NOISE

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Community noise covers all aspects of noise with the exception of occupational noise. The Regional Office for Europe of the World Health Organization (WHO), in collaboration with its Headquarters, has updated their recommendations in this field in the light of the most recent acquired technological developments

The final document is not yet published, but I have pleasure in presenting the last provisional draft before its publication. Should you wish to make any comments you are most welcome. A note inside the document indicates where to address them.

This document has been written on the following basis:

- What are the various effects of noise on health ? What sound levels can be considered as acceptable in newly planned activities ?

- The authors have then proposed guidelines related to various living environments.

- The guidelines document does not establish any recommendation regarding noise sources. This type of recommendation belongs to the regulatory field which is for state competence. Only organizations with a mandate to establish regulations can usefully propose such recommendations.

Compared to guidelines published in 1980 in the Environment Criteria Document, No. 12, the new values proposed show a slight overall decrease. However, a few new aspects related to noise such as Walkman are covered. A whole chapter is now devoted to further research needed.

It is clear that although not proposing guideline values WHO does not neglect recommendations related to:

- Noise protection measures

- Relevant transportation infrastructure to mitigate noise pollution.

- Institutional and regulatory tools necessary to implement a sound and efficient noise abatement policy.

All these aspects are covered through other projects of the Regional Office.

LE BRUIT D'AMBIANCE

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Le bruit d'ambiance couvre tous les aspects du bruit à l'exclusion du bruit en milieu de travail. Le Bureau régional pour l'Europe de l'Organisation mondiale de la Santé (OMS), en association avec le siège de l'OMS, ont tenu à actualiser leurs recommandations dans ce domaine à la lumière des acquis techniques les plus récents.

Le document final n'est pas encore publié, mais j'ai le plaisir de présenter à l'occasion de ce Congrès la dernière version provisoire avant publication. Tous ceux d'entre vous qui souhaiteraient présenter des commentaires sont les bienvenus et une note à l'intérieur du document leur précise l'adresse où les faire parvenir.

Ce document est basé sur la logique suivante:

- Quels sont les différents effets du bruit sur la santé, en fonction de ces effets quels niveaux sonores peuvent être considérés comme acceptable en fonction des activités humaines envisagées ?

- Ces valeurs-guides étant proposés, les auteurs se sont attachés à définir des valeurs-guides en fonction de l'environnement dans lequel nous évoluons.

- Le recueil des valeurs-guides de l'OMS pour le bruit ne propose aucune recommandation pour les sources de bruit. En effet, il s'agit là du domaine réglementaire propre à chaque Etat et seule une organisation ayant pouvoir d'établir des règles s'imposant à tous ses membres pourrait faire oeuvre utile en ce domaine.

Par rapport aux valeurs-guides publiées en 1980 dans les critères d'hygiène de l'environnement, No. 12, sur le bruit il y a globalement une légère révision à la baisse. De plus certains aspects récents tels que le bruit des balladeurs sont couverts. Enfin, un chapitre relativement important est consacré aux axes de recherche recommandés.

Il est évident que le fait de ne pas proposer de valeurs-guides pour les émissions n'implique pas de la part de l'OMS qu'elle néglige toutes les recommandations relatives:

- aux mesures de protection contre le bruit,

- aux infrastructures appropriées de transport pour limiter les nuisances sonores

- aux aspects réglementaires et institutionels nécessaires à la mise en place d'une politique efficace contre le bruit.

Ces aspects sont couverts par d'autres projets du Bureau régional.

PSYCHOLOGICAL APPROACH TO NOISE RESEARCH FOR FUTURE NEEDS

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Environmental pollution is a global problem and a major way of dealing with it is by saving energy and resources. One possible method of doing this is to develop new techniques for conservation. It is clearly reasonable to propose this, but practical action will face many difficulties. One is that it is not easy to reach general agreement between nations about the way in which expenses will be shared. Another is that industrial companies which develop new technology for environmental protection after huge investment probably will not like to make it available without some financial return. Finally, developing countries which have many resources will wish to exploit them in order to achieve a higher standard of living. To protect our environment and improve conditions we must recognize that we have to share the burden of cost and effort and we must take a determined attitude towards environmental problems.

Noise is not a global problem. Sound energy is not accumulated, and the area which suffers from noise is limited to that around the noise source. However, the effect of noise on man is not unimportant, as those who suffer from it would readily agree. Many machines which make noise are commonly used in many countries and can be a cause of noise problems. Acoustics can contribute to reducing noise but, like solutions to other pollution problems, this cannot be achieved without expense. In this case, as with other types of pollution, we have to consider the relation between cost and benefits.

Noise is sensory pollution. Everyone can recognize its bad effects without using measuring instruments. By taking care, everyone can contribute to the prevention of the problem to some degree, and the effectiveness of technical countermeasures is easily perceived. In some respects noise is a typical environmental problem, but its causes and consequences, and its solution, are more obvious to ordinary people. Paying attention to noise can help to cultivate an enlightened attitude towards environmental problems in general.[1]

Countermeasures against noise which require great expenditure of energy and resources cannot be adopted even if they are very effective. For example, air-conditioner noise will decrease when the speed of fan is reduced but this also reduces the efficiency of the air-conditioning. A b~~etter~~ solution is possible, though it is more difficult to achieve: the noise can be reduced without lowering efficiency by designing fans of a more effective pattern. This is just one example from among many which shows how countermeasures against noise have to be considered in relation to energy and resources. To do this effectively, the following psychological factors must be taken into consideration.

Noise is defined as "unwanted sound". The concept "unwanted" is extremely subjective and when measures are to be taken against noise its subjective quality and meaning have to be taken into account. More precise methods for predicting the effect of noise on man are being developed.

One is by finding more precise noise indices which are based on the relation between physical parameters of sound and subjective response. In dealing with noise problems, some physical features of sound are of special significance. The evaluation of noise is usually based on sound level and frequency characteristics at the listening position, but for an accurate assessment it is now clear that other factors must be taken into account.

For example, the direction from which sound comes affects the way it is evaluated.[2] This means that when a comfortable sound environment is being considered, the directionality of noise must be taken into account. This also applies to noise in a closed space such as a passenger car, where the effect of noise may vary depending on whether the irregular noise comes from the same direction as the engine noise or not. When directionality is taken into account, the technique of using a dummy head, as in architectural acoustics, is an effective method.[3]

Where temporal factors of sound sources are concerned, there are still many unsolved problems. These include the evaluation of temporal fluctuation, the method of treating the effect of a number of events and the time of day, and the question of the appropriate time constant used in evaluating impulsive noises.[4] All these are of fundamental importance to the exploration of the relation between temporal patterns and perception, both for the purpose of psychophysical inquiry and for applied research into temporally fluctuating and intermittent events, occurring together over a period of time.

The interaction between the envelope patterns of sounds when there are multiple sound sources in a room is a topic of interest and importance. As the phenomenon of co-modulation masking release indicates, when the phase of the temporal fluctuation between the background noise and the signal is not synchronized, the amount of masking decreases greatly compared with the case when they are synchronized.[5] This is related to noise evaluation, since better understanding of the temporal relation between noise and signal will increase the precision of prediction, an instance of fundamental and applied researches being combined.

If it becomes possible to evaluate the overall effect of various noise sources in a given space, the trade-off effect can be measured quantitatively as well as qualitatively. This will give guidelines for the design of spaces which provide a comfortable environment in terms of sound. An appropriate criterion of "unwantedness" has to comprehend large individual differences.[6] To solve practical noise problems effectively in real life, personal conditions must be taken into consideration.

Noise is not the only component of an environment, of course, and from a wider viewpoint, it is necessary to synthesize the effects of all the factors which constitute an environment, and their interactions.[7] It is desirable to investigate the effect of each factor, including visual perception, vibrotactile perception, olfactory perception and the perception of the quality of air, and their interactions. For example, "green belts" (woods) subjectively improve the auditory environment as well as the visual environment.[8]

Noise problems are an interdiciplinary study, and are related to ecological aspects of the environment. Their solution will be an international undertaking, calling for cross-cultural understanding.[9]

To determine what are effective countermeasures against noise, we have to consider the following practical questions on the basis of psychological understanding.

(1) The relation between cost and benefits in preventing environmental pollutions.
(2) The possibility of protection against noise without the consumption of energy and resources.
(3) The importance of composite noise rating methods.

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DEVELOPMENTS IN NOISE-INDUCED HEARING LOSS DURING THE LAST 25 YEARS

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At the time of the first Conference on Noise as a Public Health Hazard, a considerable body of knowledge existed concerning the loss of hearing associated with noise, at least industrial noise. The situation was summarized as follows: "Steady noises above 80 dBA are capable of producing some change in auditory threshold, and above 105 dBA they are sure to produce PTS in the normal unprotected ear if exposure continues, eight hours a day, for several years. We cannot reduce NIPTS except by reducing the effective noise exposure, and there is no way to restore it. Furthermore, we cannot identify the noise-susceptible individual. Therefore pre-employment and monitoring audiometry, together with a program of ear protection, is the only solution now known." These rather negative generalizations have, by and large, been confirmed by research during the intervening 25 years, although exceptions exist. No treatment has been found that will significantly ameliorate NIPTS. While there is at the moment some excitement about the possibility of reduction of NIPTS from a severe exposure through use of a "conditioning" exposure, that any such effect occurs in man has yet to be demonstrated. Individual susceptibility to PTS remains essentially unpredictable; although temporary threshold shift (TTS) is the best predictor, the correlation is small. However, vulnerability has been shown to increase under certain conditions such as use of ototoxic drugs or inhalation of carbon monoxide. No indicator of beginning damage to the auditory system that is more sensitive than a change in the pure-tone threshold has been discovered despite an intensive search by many laboratories.

One important development since 1968 has been the growth of awareness of the importance of noise outside the work situation (sociacusic noise) and of other deleterious agents such as diseases, ototoxic drugs, and blows to the head (nosoacusis). "Industrial hearing loss" data are inevitably confounded by sociacusis and nosoacusis as well as by presbyacusis. Indeed, the reason that 85-dBA industrial noise produces PTS may be because of sociacusic and nosoacusic factors. Attempts to separate contributions to PTS by industrial noise, sociacusis, nosoacusis and presbyacusis have shown some progress recently, but the process still involves considerable guesswork.

A ramification of sociacusis that is just being realized is that it throws into question the common assumption that PTS grows in the same way in the individual as in the group average. The most popular model of growth assumes that a change in hearing occurs only gradually, with successive daily exposures producing "microtraumata" that eventually add up to a measurable NIPTS. If all daily exposures were exactly the same, this model would certainly be a sensible one. However, because of high variability in sociacusic noise exposure, the total daily noise exposure may vary over a wide range. It is therefore quite possible that after the first few days or weeks of exposure to the workplace noise, only on the days when total exposure is unusually high will additional damage occur.

The growing realization of the importance of sociacusis, especially when regulations have been promulgated that prohibit daily industrial exposures greater than 90 dBA for 8 hours or its equivalent (whatever that turns out to be), has shifted the emphasis on reduction of NIPTS from industrial workers to the general population. Two main practical problems exist now as they did 25 years ago in educating people to protect their hearing: making them realize that (1) in order to be potentially hazardous, a noise need not be uncomfortably loud, but that conversely (2), a noise that is uncomfortably loud is not necessarily hazardous. In short, hazard depends not only on the level of a sound but on its duration and its temporal pattern.

This obvious and simple fact seems to have escaped not only the general public but also legislators and regulators, at least in the early 70s. The USA's 1972 Noise Control Act postulated that the Environmental Protection Agency had to determine "the levels of environmental noise the attainment and maintenance of which in defined areas under various conditions are requisite to protect the public health and welfare with an adequate margin of safety". One can perhaps forgive the framers of the Act for ignoring duration, as they were principally concerned with the annoyingness of noises, which is somewhat less dependent on duration than is their hazard to hearing.

However, the Noise Control Act led to all sorts of trouble when applied to assessing the hazard of noise to hearing. The problem was solved only by circumvention: the term "level" was applied to a measure that was really an exposure in disguise. "Equivalent level" (Leq) was the name given to the fixed A-weighted level that, had it been acting over some period of time, would have involved the same energy (the product of intensity and time) as did the actual noise over that same time. Exposure limits could then be expressed in terms of this "level". Unfortunately,however, this solution had its price. Having defined Leq, some regulation-setters (and even some scientists) decided that daily exposures should be measured only in terms of energy, with temporal pattern completely disregarded. This simplistic solution to the problem of defining "exposure" was incorporated into ISO 1999, with the result that little research to find a better measure than Leq has been undertaken.
Another misconception that ignores duration in assessing exposure is the myth of the "critical intensity" in acoustic trauma--a sound level that, if exceeded for even a very short time, will cause extensive damage. Belief in this duration-independent characteristic of the cochlea had already before 1968 led to a proposal that impulse noise be limited to 140 dB SPL, and in the original OSHA regulation of 1974, 115 dBA was stipulated to be the upper limit. We therefore had--and still have--the absurd regulation that 115 dBA can be tolerated for 15 minutes, but that 116 dBA cannot be permitted for even a few seconds.

However, most noise exposure limits developed in the past quarter century, especially those based on ISO 1999, are overprotective, and therefore are judged to "err in the right direction". If the present limits for industrial noise exposure were rigorously enforced, with hearing protection correctly used where necessary, we would have achieved one part of our goal of eliminating hearing damage from noise--i.e., the industrial NIPTS. It is unlikely that we will ever eliminate NIPTS from sociacusic exposure, but efforts to educate the public about the actual hazards--and not exaggerated hazards--of noises should be continued if NIPTS is to be at least minimized.

NOISE REGULATIONS AND STANDARDS: PROGRESS, EXPERIENCES, AND CHALLENGES

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In adding a ninth team on "Regulation and Standards" to its eight scientific teams, the International Commission on the Biological Effects of Noise had several goals in mind: the exchange of information on regulatory approaches taken Internationally, by various countries and in their local subdivisions; the reporting of successes and problems; and, perhaps above all, how the scientific community could best assist the rule and decision process. The potential health effects of noise are so manifold and the exposure conditions over a lifetime of such complex variety, that research continuously derives, proposes, and tests new criteria and dose-response relationships. These proposed changes and additions and their premature discussion outside the technical community can be a detriment to efficient regulation, enforcement, prospective planning, and public support. Review of the approaches taken over the last two decades appears to demonstrate that the combination of control of environmental exposures, occupational exposures and product noise emissions can be effective in limiting public exposure to desired levels - if consequently applied and enforced. In the use of available criteria, the clear distinction between three purposes is important: environmental impact assessment, land-use planning and dose-response health effects criteria. Unfortunately, frequently the differences between these three have been neglected. Scientific investigations, while separating these different purposes of regulations, should try to test the effectiveness of the simplest, most practical and yet protective approaches. Although few real-life noise exposure data on large populations exist, available evidence suggests, that uncontrolled, mostly voluntary leisure time exposures, make regulatory approaches not as effective as theoretically expected. In public education, product standardization, and legal noise control, the collaboration and continuing input from the scientific community are essential. To make this input coordinated and technically optimized should be the goal of the ICBEN Team on Regulations and Standards.

Standards for industrial environmental noise exposure : current UK research

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Introduction

Both of the authors are members of the British Standards Institution technical committee responsible for standards for the assessment of industrial noise as it affects people living near sources of industrial noise. The first author is Chairman of the committee. The relevant standard in the UK is BS 4142 : 1990 "Method of rating industrial noise affecting mixed residential and industrial areas" . A new edition of this standard was issued in 1990 after an extensive revision of the original document , first published in 1967 (1). Work is now in progress on a further short-term revision, due for publication at the end of 1993, and on a longer term revision over the next 3 years. As part of the strategic approach to this more extensive revision, the committee is taking account of a number of related research projects currently in progress in the UK. This paper identifies these projects and the full conference paper will summarise them and consider how the research results will be utilised in standardisation.

Current research

Contractor	Customer	Topic	Completion
ISVR	DoEnv	Quantification of tonal noise (2)	December 1992
NPL	DoEnv	Subjective and objective assessment of industrial noise (3)	December 1993
W S Atkins	DoEnv	Pilot study of disturbance due to industrial noise	December 1993
W S Atkins	DTI	Standards for industrial environmental noise exposure	December 1995

DoEnv = Department of the Environment
DTI = Department of Trade and Industry

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NOISE AND THE ART OF MAINTENANCE

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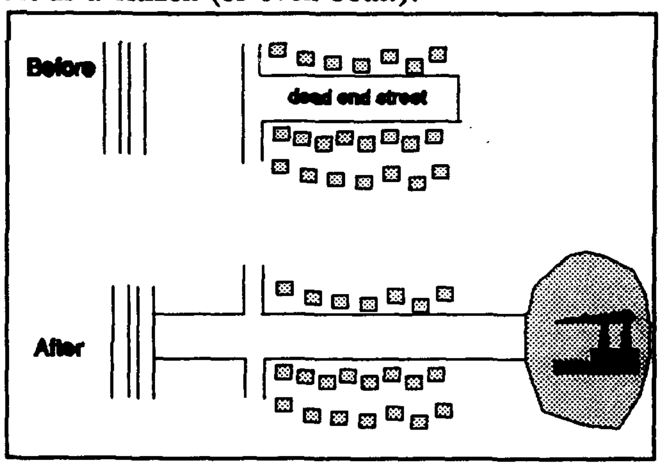
Defining noise standards is a difficult task. Luckily nowadays a wealth of scientific knowledge is available to help policy makers in making decisions.
Once the standards are agreed upon, they will have to be implemented in society, which in most countries (but not all) goes by way of some form of regulation. This may be a formal law, or regulations of lower order.
These regulations will have to take into account three "threats" to the noise environment:

(1) New noise sources
(2) New noise sensitive elements near an existing source
(3) Changes in existing more or less noisy environments

Problem number three is particularly difficult to handle in maintaining the acoustic quality agreed on.
To illustrate the problem, lets face a situation common to almost everyone who has anything to do with noise, be it in a professional sense, or just as a citizen (or even both!).
Suppose we have a residential area, with some houses on a broad, but dead end avenue. Traffic is almost neglectable. After having won the elections, the community council decides to build an industrial area, not far from this residential area. The cheapest way to provide access to the industry is by way of a road to the nearest motorway. The broad avenue is just suitable make part of the access way. So one day the inhabitants of this once so quiet neighborhood are woken up very early by heavy trucks who pass in front of their bedroom windows.



In this case, at least, it is clear who has caused the trouble. More often though, it is not so easy to point out the party or parties responsible for a sudden or a slow rise in environmental burden.
The principles to be discussed are:

1. Fixing a noise load in time
2. Forms of monitoring changes
3. Means of counteracting increases
4. Responsibilities: who can be addressed for what.

INTERNATIONAL ASPECTS OF NOISE STANDARDS COMPARED TO OTHER ENVIRONMENTAL FACTORS

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1. Main results of the "United Nations Conference on Environmental and Development" (UNCED) Rio de Janeiro (Brazil) in June 1992.

2. Major Requirements for UNCED as laid down in the UN General Assembly'Resolution 44/228 and the role of Noise Control.

3. Priorities of environmental issues and the relations to noise effects and noise abatement.

4. Characteristics of noise load in the population.

5. Costs of noise control.

6. Noise control in the industrialized and in development countries.

7. Evaluation, importance and planning of noise control in different developed countries.

8. Examples of cooperations between institutions resp. nations dealing with problems

NOISE AND COMMUNICATION, GENERAL INTRODUCTION

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The theme "Noise and Communication" covers a wide range of topics, all related to some form of communication (e.g., speech or warning signals), under the influence of one or more disturbing factors, with the emphasize on the effect of ambient noise. Such topics may include characteristics of the *source signal* (speech, either direct or via telephone or Public-Address systems, or specific warning sounds), characteristics of the *environment* (ambient noise, reverberation), or of the *listener* (native versus non-native language, hearing loss, the use of ear-protection devices). A systematic overview of this field will be presented, indicating the areas for which design criteria and guidelines are readily available, and areas for which more research is needed.

This academic approach of identifying "areas which require more research", will be supplemented by a more pragmatic approach : Formulate a variety of practical questions related to our field of expertise, and see to what extend we can supply the necessary information for answering these questions. Examples of such questions are : (1) specify the characteristics of a warning signal for a noisy working environment, to be recognized and localized by young people using ear plugs, or (2) what design criteria should be used for a Public-Address system in a noisy and reverberant environment for an audience including elderly and non-native listeners ? This pragmatic approach provides interesting information on the relevance and the (in) completeness of the expertise in the field of noise and communication.

METHODS TO PREDICT AND ASSESS SPEECH COMMUNICATION AND SIGNAL RECOGNITION WITH REGARD TO STANDARDIZATION.

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Speech communication is an important part of the activity at work, in school, at home and during leisure time. Recognition of warning signals is a part of the safety system for work and traffic.

In Europe a new EC directive about a safety lable has been issued. Is also contains regulations for warning sounds and speech communication.

The technical committees of ISO and CEN deal with these subjects. ISO/TC43 "Acoustics" presents a standard concerning emergency signals. ISO/TC159 and CEN/TC122 "Ergonomics" have prepared standards for a system of danger signals with the speech interference level, the modified articulation index, and speech communication via electrical systems (microphone - earphone). A standard with regard to acoustic danger signals has been finished.

These standards include the influence of ambient noise, distance between speaker and listener, vocal effort, wearing of hearing protectors, shouted speech and hearing loss.

The methods described in these standards to assess the speech communication and their advantages are discussed.

THE EFFECT OF HEARING PROTECTIVE DEVICES ON DIRECTIONAL HEARING IN QUIET AND NOISY SURROUNDINGS

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This investigation was conducted to compare the effects of a conventional muff and plug and a level-dependent stereophonic muff with limited amplification on directional hearing. Two groups of 24 normal-hearing listeners, aged 18-38 and 41-58 yrs. respectively, participated. Sound localization ability was assessed in a semi-reverberant chamber, using an array of six speakers, positioned at a distance of 1 m from the subject at ear level and at azimuth angles 60° apart, i.e., at 30°, 90°, 150°, 210°, 270°, and 330°. The stimulus was an 80 dB SPL one-third octave noise band. Two centre frequencies above and below 1500 Hz were tested, so that interference with interaural disparities in time of arrival and intensity, cues to spatial location, could be assessed independently. The experiment was conducted in quiet and in a moderately loud continuous noise background. In all, there were sixteen experimental conditions defined by combinations of levels of ear (unoccluded, E-A-R plug, E-A-R 3000 muff and Bilsom 2392 muff), background (quiet and 65 dB SPL white noise) and stimulus frequency (500 Hz and 4000 Hz). One block of 120 trials was presented for each condition. Within a block, the test sound emanated randomly from each of the six speakers on 20 trials. In both groups, accuracy was highest in the unoccluded condition and decreased significantly when protectors were worn. With the low-frequency stimulus, there were no differences among protectors. In contrast, with the high-frequency stimulus, performance was similar for the conventional muff and plug but declined significantly when the level-dependent device was worn. This was largely due to a relative increase in the proportion of right/left confusions. Although age was not a significant main effect, the younger subjects but not the older were adversely affected by the presence of the noise background. For both groups, there was no effect of frequency with the plug. However, with the muffs, performance was significantly better at 500 Hz than at 4000 Hz.

HEARING HANDICAP ASSESSMENT FOR SPEECH PERCEPTION IN INDUSTRIAL NOISE BASED ON PURE TONE AUDIOMETRY

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At the previous meeting in Stockholm we presented a paper on the relation between the tone audiogram for individuals with noise-induced hearing loss and their speech reception thresholds (Smoorenburg, 1990). The speech reception thresholds were measured both in the quiet condition and in noise. The results showed that high-frequency hearing loss, typical for noise traumata, particularly affects speech reception in noise. These data were collected for noise shaped after the speech spectrum. It was argued that, to a great extent, hearing handicap will be experienced during social gatherings where the ambient noise is speech noise. However, speech communication at the work place is another condition that should be evaluated. The present paper addresses this subject.

700 industrial spectra collected by the Institut für Lärmbekämpfung in Mainz (1979), including 100 spectra of the NIOSH data base, were analyzed statistically in order to define a limited set of representative spectra. The analysis yielded four spectral shapes that cover most of the spectra found in industry. Subsequently, stationary noises were shaped in accordance with these four spectra and used in the speech reception experiments. The four noises were supplemented by a fifth noise shaped in accordance with the for industrial noise most representative spectral distribution but 100% sinusoidally modulated in order to study temporal aspects of noise interference with speech reception for individuals with noise induced hearing loss.

Speech reception thresholds were determined for 40 subjects with different degrees of noise-induced hearing loss while the five noises were presented at 50 and 80 dB(A). The present paper will discuss the relation between the tone audiogram and the speech reception thresholds measured in the five noise conditions and the possibility of predicting these thresholds from the tone audiogram using procedures such as the articulation index method.

Smoorenburg, G.F. (1990). Hearing handicap assessment for speech perception using pure tone audiometry, in: "Noise as a Public Health Problem, New Advances in Noise Research", Part I, Vol. 4, Swedish Council for Building Research, Stockholm, Sweden, 245-254.

AUDITORY WARNING DESIGN

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A number of models now exist whereby appropriate loudness levels for auditory warnings in noisy environments can be predicted. However, psychological features of auditory warning signals are less well researched although this too ultimately has important consequences for warning design and implementation. With digital technology it is possible to design potentially useful features into warning sounds. One of these is perceived urgency; that is, an indication of the urgency of situation can be built into the warning itself, through the manipulation of the sound parameters used in its construction. Thus even if the meaning of a warning is unknown, the listener can elicit some indication of the urgency with which he or she should act from the implicit urgency of the warning sound. In order to design such features into a warning, it is necessary to chart the effects of a range of sound parameters on perceived urgency. This paper describes a series of experiments in which the effects of a large range of spectral, temporal and melodic characteristics on the perceived urgency of auditory warning parameters were explored. The results show that many features have strong and robust effects on subjective judgements of urgency. In a further study, a set of warnings was designed in which the order of urgency was predicted prior to experimentation; the results obtained correlate very highly with the predicted order, showing that designing perceived urgency into warnings is possible.

A further set of experiments is described in which the most important sound parameters in auditory warning design, such as speed and pitch, were explored in greater detail using an application of Steven's Power Law. These experiments demonstrate the relative strengths of individual sound parameters on perceived urgency by quantifying the power of the relationship between objective values of acoustic parameters and subjective judgements of urgency.

These research findings have a number of applications in the design of auditory warnings both for the present and for the future.

MODERN TECHNIQUES FOR IMPROVING SPEECH INTELLIGIBILITY IN NOISY ENVIRONMENTS

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This paper reviews methods for estimating speech intelligibility, and discusses the latest technology for loudspeaker and/or microphone arrays for improving speech intelligibility. Speech intelligibility (SI) in reverberant and noisy conditions is a primary objective for acoustic engineering. Moreover, designing an acoustic space which has both high intelligibility and full spaciousness is a primary objective for concert hall acoustics.

Miyata and Houtgast (Proc. of Eurospeech 91, 289-292) proposed a new method that uses an exponentially decaying time window function for determining the MTF in a reverberant space. Intelligibility tests using a variety of computer-generated squared-impulse responses confirm that their method is better than the ordinary MTF method.

When speech is recorded with a microphone in a room, the sounds produced by the speaker may reach the microphone by many separate paths. To preserve the SI, we must maintain either a high energy ratio between the sounds received directly from the speaker and the time-delayed reflections (*D/R*) or a high energy ratio between the direct sound and the room noise (*D/N*). Nomura, Miyata, and Houtgast (Acustica 77, 253-261) described the theoretical increase in *D/R* and/or *D/N* that can be obtained by using microphone arrays. They used calculations based on the statistical properties of a diffuse sound field. Their technique is useful for improving the SI in a reverberant and/or noisy room. Another approach was taken by Kaneda and Ohga (Proc. IEEE, ASSP 34, 1391-1400). They developed a small-sized microphone array using a sophisticated adaptation algorithm. Their array technique is also effective at reducing "directional" noise source signals.

The importance of the initial portion of the reverberant energy decay curve has been pointed out for subjective effects in non-exponential decay fields (J. A. S. A. 58, 853-857). Nomura, Miyata, and Houtgast (Acustica 69, 151-155) performed SI tests in a reverberation room with an absorbent floor where non-exponential decay fields occur. A highly absorbent floor can greatly improve the SI, even though the total reverberation time is still long. It should therefore be possible to design an acoustic space can be designed to have both high intelligibility and full spaciousness.

The MTF for SI is based on the monaural criterion of sound fields. Normal human listeners, however, hear speech signals under "dichotic" listening conditions. Therefore, we can expect the SI to be increased by binaural listening in sound fields. Howere, this is, a complicated issue and is still under investigation (Miyata, Nomura, and Houtgast, Acustica 73, 200-207; Nakajima and Ando, J. A. S. A. 90).

RESEARCH ON NON-AUDITORY PHYSIOLOGICAL EFFECTS OF NOISE SINCE 1988: REVIEW AND PERSPECTIVES

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ABSTRACT

As the range of non-auditory physiological effects of noise is very broad, the studies which deal with these effects automatically show high variability. Traditionally, many studies are laboratory experiments examining acute physiological effects using humans or animals as subjects. In the psychophysiological area noise stimuli are often used as classic paradigm for the analysis of stress mechanisms and stress effects of the cardiovascular and endocrine system. Furthermore, with increasing development of technical methods, it has become possible to investigate noise effects also in physiological subsystems (e. g. coronary blood flow, cerebral circulation).

The results are mostly the same: Noise stimulates the autonomic nervous system to a higher ergotropic level and therefore has to be considered as a stressor. The pattern of physiological responses can be partly modified by individual factors like habituation, predictability of noise stimuli, sensitivity to noise etc..

Despite the high plausibility of the biological model, the epidemiological evidence of the harmfulness of chronic noise exposure is very weak. The main interest still is focussed on the cardiovascular domain where noise might be a more or less serious risk factor among others. Cross-sectional studies continue to predominate, prospective studies are desirable. All studies are highly susceptible to confounding, effect modification or other problems (low response rate, occupational versus environmental noise exposure, use of hearing protection, interactive influence of other stressors). Studies to date show contradictory results. The hypothesis, that prolonged exposure to high noise levels implies e. g. an increased risk for hypertension or ischemic heart disease neither can be confirmed nor rejected. Prevalence ratios for hypertension between high and low noise groups range from 0 to 3.1. Differences in mean systolic blood pressure detected are relatively small (0-10 mmHg). Findings related to cardiovascular effects other than blood pressure are not consistent.

While no individual study is persuasive regarding the association between industrial noise exposure and elevated blood pressure, research as a whole suggests that such an association exists among persons working for prolonged periods of time under extremely high noise levels without ear protection. Furthermore, preliminary results from Caerphilly indicate, that there is an increased risk for those exposed to traffic noise who are also exposed to high levels of occupational noise

Another important problem is the potential adverse effect of noise on critical groups like pregnant women and their babies, the sick, the young, the elderly or persons with high sensitivity to noise.

As results from studies of high speed or low altitude flight indicate, children and the elderly may be vulnerable to blood pressure effects from this noise source. Yet, interpretation of these results is difficult because of low statistical power and inability to adjust for confounders.

Mental health seems to be related to noise sensitivity and noise annoyance with the prevalence of psychiatric symptoms being higher among the more annoyed or more noise sensitive people.

Effects on pregnancy remain unclear. To date, no chronic effect of noise such as increase of malformations has been observed, whereas the reactivity to noise stimuli seems to be augmented during pregnancy.

The current findings cannot support a consistent relationship between noise exposure and harmful physiologic health effects. However, this cannot be construed as evidence of no effect of noise on non-auditory health because of the poor quality of the studies. These circumstances only indicate that further rigorous studies of noise effects on health are greatly needed.

ROAD TRAFFIC NOISE AND HEART DISEASE RISK: RESULTS OF THE EPIDEMIOLOGICAL STUDIES IN CAERPHILLY, SPEEDWELL AND BERLIN

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The hypothesis that prolonged exposure to road traffic noise causes ischaemic heart disease (IHD) was tested in cross-sectional, case-control, and cohort studies in middle-aged men. The studies were carried out in the small British town of Caerphilly, a part of the British town Bristol named Speedwell, and the German city Berlin.

From numerous noise experiments it is well known that noise acts as an unspecific stressor upon the human organism stimulating the central nervous system, thus affecting sympathetic and humoral activity. Many of the physiological parameters affected in the laboratory experiment are those which are known as risk factors for cardiovascular disease. It is understood that noise may be harmful if accompanied by strong emotional stress reactions. Also, sleep research has shown that noise stimuli may affect sleep quality. However, the long-term effects of chronic exposure to environmental noise, and thus to such direct (sleep) and indirect (emotional stress) stimulation is unknown. From the public health point of view, the question whether subjects who live in noisy streets run a higher risk of disease or not is of interest, taking all their individual coping strategies in real life into account. To answer this question, epidemiological studies are required.

In the Caerphilly and Speedwell studies, 2512 and 2348 men, respectively, aged 45-59 years were seen in the initial cross-sectional phase and at intermediate follow-up intervals of 5 and 3 years, respectively. The prevalence ratio (95% confidence interval) of IHD at the beginning of the studies was 1.2 (0.7-2.0) and 1.2 (0.8-1.9) for men in the highest-noise category of the daytime outdoor traffic noise level (66-70 dB(A)) as compared to those in the lowest-noise category (51-55 dB(A)) after adjustment for possible confounding. The risk factor profile of these men was slightly shifted towards a higher IHD risk. It was calculated that a relative risk of IHD incidence of 1.1 was to be expected for those men. In the first follow-up investigations, crude relative risks of 0.9 (0.4-1.9) and 0.8 (0.4-1.6) were observed. These, however, were based on very few cases (below 10) in the highest-noise group.

In the Berlin case-control studies, comprising a pre-study and a main study, 121 and 693 male patients (survivers), respectively, with acute myocardial infarction (MI) and 152 and 3865 controls, respectively, were seen. The subjects were aged 41-70 years. The odds ratio of IHD incidence was 1.3 (0.5-3.8) and 1.2 (0.8-1.7), respectively, for men in the highest-noise category (71-80 dB(A)) as compared to the lowest-noise category (51-60 dB(A)) after adjustment. In a subsample of men who had not moved within the past 15 years, the odds ratio was 1.3 (0.9-2.0) which was borderline significant ($p<0.10$). Also, cross-sectional analyses of self-reported MI among the random sample of controls revealed a relative prevalence of 1.2 (0.7-2.0) for men who had not moved within the past 15 years in the highest-noise category.

Some methodological issues and the relevance of low relative risks will be discussed.

ROAD TRAFFIC NOISE, NOISE SENSITIVITY AND PSYCHIATRIC DISORDER; PRELIMINARY PROSPECTIVE FINDINGS FROM THE CAERPHILLY STUDY

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Abstract:

Does environmental noise exposure cause psychiatric disorder? Earlier cross-sectional studies have related noise exposure to psychological symptoms but these may have been biassed by choice of low noise control samples, and by respondents' knowledge of the survey's purpose. Epidemiological surveys using standardised measures of psychiatric disorder have not found an association but subjects in high noise also may be survivors in noise, the most vulnerable to noise having moved away. Psychiatric hospital admissions according to home noise exposure level have shown mixed results.

If noise has no overall pathogenic effect on the population it might have deleterious effects on the health of certain sub-groups, for instance, people sensitive to noise, as there is a well proven association between noise sensitivity and psychiatric disorder and in one study noise sensitivity as part of a group of asthenic sub-clinical symptoms has been found to predict further depression.

The effects of road traffic noise and noise sensitivity on the development of psychiatric disorder is reported from the preliminary results of the prospective phase of the Caerphilly Study. This study is a prospective epidemiological community survey of the determinants of coronary heart disease and its risk factors based on the small town of Caerphilly in South Wales, U.K. Psychiatric disorder was measured by the General Health Questionnaire and noise sensitivity by the 10-item Weinstein scale. In the cross-sectional analyses of 2398 men there was no association between noise exposure and psychiatric disorder except, paradoxically, among those of intermediate and low noise sensitivity where rates of psychiatric disorder increased with increasing noise levels. In the highest noise sensitivity group there were high levels of psychiatric disorder regardless of noise. This might be explained by noise sensitivity partially measuring a tendency to over-report symptoms. Initial prospective analysis in this cohort has found no associations between traffic noise level at baseline and later psychiatric disorder but has found a small significant association between noise sensitivity and the risk of future psychiatric morbidity. This finding is still present among men who did not have psychiatric disorder at baseline. It appears that noise sensitivity is an indicator of future vulnerability to psychiatric disorder but it does not seem to confer psychological vulnerability to the effects of traffic noise in this sample.

A DOSE-RESPONSE RELATIONSHIP BETWEEN CUMULATIVE NOISE EXPOSURE AND HYPERTENSION AMONG FEMALE TEXTILE WORKERS WITHOUT HEARING PROTECTION

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Cumulative noise exposure (CNE) was investigated as a risk factor for the prevelance of hypertension in 1101 female textile workers using a logistic model. The results showed that CNE, Which incorporates both dBA level and duration of exposure, results in a dose-response relationship whit hypertension and, at the same time, reduces the high correlation between age and working years.

Using a logistic model, the adjusted odds ratio (OR) for CNE was 1.033 ($p=0.034$) which was slightly higher than sound pressure level alone when noise exposure was represented by dBA and working years treated as independent variables. In the CNE model the OR for age was 1.157 ($p<0.001$) versus 1.101 ($p=3.323$) in the alternative model.

This finding supports the hypothesis that CNE may be a more appropriate measure of risk for hypertension due to exposure to continuous noise and it results in a model consistent with the known effect of age on hypertensive risk. The OR for parental hypertensive history and self-reported salt intake was very nearly equal between the two models. Using likelihood measures, the contribution of age showed three times the influence of noise exposure where parental hypertensive history and salt intake were 2.0 and 1.6 times more important than noise exposure.

COMPARISON OF ACUTE REACTIONS AND LONG - TERM EXTRA-AURAL EFFECTS OF OCCUPATIONAL AND ENVIRONMENTAL NOISE EXPOSURE

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Occupational noise exposure causes acute increases of noradrenaline and blood pressure, which are correlated to the noise level. Traffic noise exposure during several hours of lectures, which reduced the intelligilibilty of syllables but not of sentences, had similar effects. Intensive noise exposure causes changes to the ST-interval of the ECG, indicating myocardial ischemia in risk persons. Another acute effect is an increase of total cholesterol, which remained elevated over a period of 30 days under daily occupational noise exposure. Magnesium, a recently detected risk factor for angina pectoris and sudden cardiac death, is decreased under noise exposure by elevated excretion. The mechanism involves increased aldosterone, increased membrane permeability via cATP, a temporary increase of Mg in blood serum and a longer lasting decrease of intracellular Mg detected in erythrocytes, vascular walls and in the myocardium.

Pathological effects of environmental noise exposure such as tension or annoyance are usually accompanied by increases of noradrenaline or adrenaline. Nocturnal noise exposure, which alters the time pattern of sleep phases causes adrenaline secretion from the adrenal medulla. A decrease in the number of lymphocytes occurs quite often. During the day after nocturnal traffic noise exposure vegetative symptoms such as fatigue, concentration impairment, headache etc. are described and, as an after-effect of adrenaline elevations, increases of blood pressure and free fatty acids are to be expected.

Long-term health defects such as chronic increases in blood pressure, cholesterol or other risk factors for myocardial infarction, are usually only caused by occupational noise exposure if this exposure has also a potential for inner ear damage. The partial use of ear protectors increases the variance of noise exposure to such an extent that dose response relations for aural and extra-aural noise effects cannot be established. The combination of such occupational exposure with nocturnal traffic noise exposure, however, causes an increase of blood pressure and total cholesterol, the latter being significant. Long-term environmental noise exposure alone caused a significant increase of plasma viscosity, a newly detected risk factor for myocardial infarction. A decrease of erythrocyte Mg was significantly correlated to annoyance caused by long-term environmental noise exposure.

EFFECTS OF AIRCRAFT NOISE ON THE PREDATOR-PREY ECOLOGY OF THE KIT FOX (*VULPES MACROTIS*) AND ITS SMALL MAMMAL PREY.

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Many low-altitude military aircraft training routes in the United States are located in desert areas. Ambient sound levels in these areas are very quiet, with A-weighted hourly averages ranging around 20-40 dB. Because they are nocturnal, many desert species depend on acute hearing for survival. We present the initial results of a three year study of the effects of heavy low-altitude aircraft traffic on the predator-prey ecology of two such species, the kit fox (*Vulpes macrotis*) and the kangaroo rat (*Dipodomys* spp.) The study is being conducted on the Barry M. Goldwater Gunnery Range (BMGR) in Arizona, USA, where these species are exposed to low-altitude overflights of F-15, F-16 and A-10 aircraft at rates greater than 70 flights/day and sound levels that often exceed 100 dB(A). Potential effects include hearing damage, sleep interference, masking of predator and prey sounds, and changes in population parameters.

Exposure is being quantified on a 1 km grid to "map" aircraft noise exposure. This noise map will be compared with small mammal density, age/sex composition, species diversity, recruitment, and survivorship on 1.4 ha study plots. These measures are also being compared with data from matched unexposed plots. Fox home range locations, sizes, and centers of activity are also being compared with the noise map. In the laboratory, sleep interference, prey and predator detection, and noise-induced changes in hearing are being investigated using an aircraft noise simulation system developed by BBN Systems and Technologies for the U.S. Air Force.

During the 1991-1992 field season, populations of small mammals and foxes were high in both exposed and unexposed areas. Small mammal densities exceeded 31-35 individuals/ha. There were no significant differences in small mammal density between the exposed and unexposed sites ($p > 0.05$); however, Merriam's kangaroo rat (*D. merriami*) was less common on the exposed study plots in every month. Foxes were more common on the exposed site based on several biased measures, specifically, the number trapped (12 on the exposed site vs. 5 on the unexposed), trapping success (1.4 foxes/km of trapline vs. 0.6 foxes/km of trapline) and number of dens identified (1.25 den/km^2 vs. 0.22 den/km^2). The highest density of dens was located in the most heavily exposed area. The six individuals that were radio-tracked had home range sizes averaging 4-5 km^2, with at least two successful pairs having home ranges completely within the area most heavily used by aircraft. Juvenile kangaroo rats and pocket mice (*Perognathus* spp. and *Chaetodipus* spp.) were found in 60% of scat samples found in the area (N=30); adult kangaroo rats were found in 20%. The higher density of foxes and lowe density of Merriam's kangaroo rat in the exposed areas is suggestive, but subtle differences in vegetation and rainfall between the control and exposed areas could also explain the differences. In the next two years of the program, the possible causes of the differences in fox distribution and kangaroo rat density will be examined further.

THE EFFECTS OF LOW-ALTITUDE AIRCRAFT ON DESERT UNGULATES

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Abstract.--We evaluated the effects of simulated low-altitude jet aircraft noise on the heart rate for six captive desert mule deer (*Odocoileus hemionus crooki*) and five mountain sheep (*Ovis canadensis mexicana*). Following this experiment we monitored the heart rate of five mountain sheep in a 3.2 km^2 enclosure as F-16 jet aircraft flew overhead. In the first study conducted at the University of Arizona, Tucson, from May 1991 to April 1992, penned animals were exposed to simulated noise from jet aircraft (range = 92-112 decibels [dB]) during three seasons (n = 112 overflights/season). We compared heart rates during simulated overflights to heart rates obtained prior to and after treatments. We documented differences between heart rates for animals, noise level, and number of overflights between seasons. All animals become habituated to sounds of low-altitude aircraft. Although heart rates increased during overflights they returned to resting rates in $\leq$ 2 minutes. Results were similar for the second part of the study where we monitored heart rate of five mountain sheep from May 1991 to March 1992 in a 3.2 km^2 enclosure in Nevada. We established three one-month periods when F-16 aircraft flew over the enclosure. We recorded heart rate 15 minutes prior to, during, and after overflights. Heart rate increased above normal in 21 of 242 overflights, however, they returned to normal within 2 minutes. We concluded that F-16 aircraft flying over mountain sheep do not create increases in heart rate that are detrimental to mountain sheep.

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THE EFFECTS OF AIRCRAFT OVERFLIGHTS ON AN ALASKAN CARIBOU HERD
Team 7

Concern over the effects of low-level, sub-sonic overflights by military jet aircraft on wildlife prompted the U.S. Air Force to commission a research program designed to address these concerns on a wild ungulate species. Caribou (*Rangifer tarandus granti*) from the Delta Herd in Interior Alaska were selected for study because detailed energetics models are available for this species and because this herd occurs near Eielson Air Force Base. The goal of the research program was to quantify the behavioral responses of caribou to low-level, sub-sonic jet aircraft overflights, and to incorporate these findings into a model that can predict the energetic consequences of repeated overflights. To accomplish this goal, we recorded the responses of wild caribou to low-level overflights, including instantaneous reactions, activity, group dynamics, and spatial movements, and we measured noise exposure levels using stationary noise monitors and proto-type "Personal Noise Monitors" mounted on individual animals.

Controlled disturbance events (i.e., overflights) were conducted in 1991 during late winter (April), post-calving (June), and the insect season (July-August) to account for seasonal differences in responses to disturbance. Observers were positioned to direct the overflights, observe caribou, and record noise exposure levels.

During three 7-10 day field sessions, we recorded the reactions of caribou to 161 overflights by A-10 (n = 95), F-15 (n = 62, and F-16 (n = 4) jet aircraft. The mean altitude of the overflights was 175 m, and the estimated mean SEL(A) for the caribou under observation during all overflights was 98.5 dbA (SD = 9.92 dbA; max. = 122 dbA). Approximately 76% of the groups under observation during overflights showed some degree of overt behavioral reaction to the aircraft, but only 30% of the overflights caused the animals to move. Groups that moved in response to overflights were displaced a mean distance of 25 m. More typically, caribou interrupted their ongoing activity for a brief time (mean duration of reactions was 20 sec) to evaluate the disturbance and then resumed an undisturbed activity (e.g., feeding). Additional data analysis is ongoing and the data eventually will be integrated into the energetics model.

BEHAVIOURAL PATTERNS OF DOMESTIC ANIMALS AS INDUCED BY DIFFERENT QUALITIES AND QUANTITIES OF AIRCRAFT NOISE

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It was investigated whether or not low altitude flying events of eight different types of aircraft will influence productivity, reproduction and behaviour of seven animal species (horse, cattle, pig, poultry, turkey, mink and dog), which were kept under different management conditions as well on pastures as in stables. Here the ascertained behavioural patterns will be presented.

The aircraft types were
- the five fixed wing aircraft Fiat G 91, F 104 g (Starfighter), F 4 f (Phantom), ALPHA Jet and A 10 (Warthog) and
- the three helicopters Alouette II, Bo 105 and Bell UH 1 D.

The fixed wing aircraft normally fly a straight ahead course at high speed, exempted the A 10, which is able also to fly low speed with quite narrow turns.
The helicopters however, have the abilities to fly relatively fast or slow or even to "hover" without any locomotion and also suddenly to put in an appearence from e.g. behind a forest ("Waldsprung, forest jump"), so that there is neither an optical nor an acoustic effect for early warning of the animals.

One group of horses had been kept on a quite large pasture (100 m long and 30 m wide), which was limited by a wooden fence. During the first blocks of overflights by fixed wing aircraft and helicopters the animals showed very intensive flight reactions along the fences or in random movements, especially when the aircraft could be seen approaching early (acoustic **and** optical as well as perhaps tactile and olfactorical effect, by the helicopters). During the later overflights the animals prefered to move towards the exit of the pasture. The fences were never broken or passed. Occasional biting or biting-treats as well as kicking or kicking-treats were also observed. No accidents or injuries could be seen and the visible excitement did not last for longer than two minutes.
A second group of horses stood in paddocks (4m to 4m each). The helicopter type Bo 105 performed "pendulum" flights, moving towards the animals and pulling back like the swing of a pendulum. During such flights and the first straight ahead overflights, the animals showed the most intensive - but of course locally restricted - locomotions. During the hovering of the helicopters, only five meters above, the horses most of the time stood motionless.

The first group of cattle, freely roaming on the pasture, showed some general unquietness. without stronger locomotion in reaction to the direct overflights of the fixed wing aircraft. Contrary to these observations the cattle moved plainly recognizable under the direct overflights of the helicopters. .No panic flight movements or stampede like behaviour had been seen.
The second group of cattle however, which also was exposed to different types of overflights including the forest jumps jostled then into a corner of the pasture and continued moving as a unified group towards the exit. On the periphery the first animals were pushed against the fence by the following ones, so that two of them were climbing through the horizontal crossbeam's of the fence. When the helicopter left from overhead the pasture, the group dispersed and the animals showed orientation behaviour and tried to hold optical contact with the person which was looking for them.

The other species mentioned above (pig, poultry, turkey, mink and dog) were kept under the same or similar overflight conditions and showed their species specific behaviour, but mostly in a quite soft expression.
These further results will be described in detail in the full paper.

AN OVERVIEW OF USAF STUDIES ON THE EFFECTS OF AIRCRAFT OVERFLIGHT NOISE ON WILD AND DOMESTIC ANIMALS

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The United States' National Environmental Policy Act requires that the US Air Force assess the impact of proposed operations on the environment. For this reason, the US Air Force's Noise and Sonic Boom Impact Technology (NSBIT) program office has planned, developed and orchestrated a program to assess the impact of aircraft noise on animals, both wild and domestic. The Air Force's research program examined the current state-of-knowledge, determined technology gaps in our current understanding, assessed the greatest needs for additional research, and executed the research plan. This presentation will provide an brief overview of the research accomplished to date for both domestic animals and wildlife. For domestic animals, NSBIT contracted studies to examine the effects of aircraft overflight noise on domestic turkeys, pregnant mares, and on milk production in dairy cattle. As a result of the these studies, as well as the compilation of previous research, a model has been developed to predict the effects of aircraft noise on these domestic animals. For wildlife, several studies will be presented concerning bighorn sheep, caribou, kit fox, and birds of prey. Dose-response models for various types of wildlife are also being developed. In addition to the results of these studies, NSBIT's future research plans will be presented.

SYNOPSIS OF STUDIES ON COMBINED EFFECTS

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During the last years a marked positive progress has been taken place in the field of studies on combined effects of and interactions between environmental factors. Many plausible results have been obtained in theoretical issues, in practical research work, in establishing the special journal in use as well as in international meeting business of the scientists of the field. Concrete and good indicators for the fruitful work of this kind are the tens of tightly controlled and often interdisciplinary studies carried out both in the laboratory and in the field, the periodical Archives of Complex Environmental Studies and the world wide ICCEF 90 and 92 Conferences with their highly ranked proceedings. Besides describing the various studies and the progress involved the author introduces the very new consensus on concepts and terminology for combined-action assessment. This Saariselkä Agreement may form the nucleus for future standards in the field of combined action assessment. In order to underline the fact that the combined actions and the combined effects of various environmental factors are very common in everyday working and functioning environments the author gives a list of examples with recorded sound samples and detailed figures from the working spots where the employees in addition to noises are simultaneously exposed to two, three or four other work or environment related physical, chemical or ergonomical factors. Recent observations done in the Finnish small business enterprises point out that especially grinders, turners, gnawers, borers, clip machine operators, plate makers, welders, fitters and assembly workers are such people who regularly are subjected to multifactorial exposure conditions concerned.

ANALYSIS OF BRAIN ACTIVITIES TO THE COMBINATION OF NOISE AND OTHER ENVIRONMENTAL FACTORS DURING MENTAL AND PHYSICAL LOADS

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It is recognized that the effects of noise on brain activities differ in accordance with the physical factors of sound pressure level (SPL), frequency, exposure patterns, etc.. It may be the same as the effects of noise combined with other environmental factors such as air temperature, illumination, etc.. However the combined effects of environmental factors with or without work are not clarified adequately. In the present study how brain activities react to the combination of noise and illumination during mental or physical work was investigated by using maximum entropy spectral analysis of ectroencephalograms (EEG), somatosensory evoked potentials (SSEP), heart rate (HR), urinary catecholamines, work amount of VDT and 30 items of subjective symptoms.

Healthy male students with normal hearing between the ages of 19 and 22 were given visual display terminals (VDT) work for one hour under four kinds of environmental condition:(1) without noise exposure under 700 lx illumination; (2) with 70 dB hearing level (HL) white noise exposure under 700 lx illumination; (3) without noise exposure under 300 lx illumination; (4) with 70 dB (HL) white noise exposure under 300 lx illumination. Brain waves were derived from Cz, Pz, OL and OR (International 10-20 system) referenced to the both earlobes using a palate electrode before and after the work. SSEPs were recorded from C_5S-Fz, C_3-A_1 and C_3-Ep_1 before and after the work with 500 times electric stimuli of 3.5- 5.8 mA and 100 ms in duration to right median nerve triggererd at H wave of ECG. Urinary dopamine (DA), norepinephrine (NE), epinephrine (E), HR and SS were also measured before and after the work.

Theta wave of EEG spectrum under the condition of white noise exposure and 700 lx illumination decreased in compared with the condition without noise at the same intensity of illumination. Increase in alpha wave under the condition of 300 lx without noise and decrease in alpha wave under the same intensity of illumination with 70 dB white noise exposure were shown. Peak latencies of N_{13}, N_{14} and N_{20} SSEP didn't significant changes in four kind of conditions. Heart rate showed some changes under the conditions of high or low intensity of illumination and with or without noise exposure. Work amounts of VDT works increased in the order of the conditions under 700 lx illumination without noise, with 70 dB white noise exposure, under 300 lx illumination without noise, and with 70 dB white noise exposure, but the amount of subjective complaints was the contrary.

CHANGES IN BRAIN FUNCTIONS DUE TO NOISE AND ITS COMBINATION WITH BRAIN AFFECTING SUBSTANCES

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Noise induced and sound induced cortical DC-shifts as well as auditory evoked potentials are changed by different brain affecting substances and their combinations.

In animal experiments using chronically implanted electrodes specially constructed for DC-recordings information related as well as intensity related cortical DC-shifts to noise and sounds were recorded. The DC-shifts during a 27 sec exposure to a series of physiologically meaningful sounds (battle cries) were compared with the reactions to an energy equivalent white noise. The white noise lead to a smaller on-effect and an earlier return to the baseline. In combination with the influence of CO this return to the baseline was accelerated especially in the condition with meaningful sounds.

Concerning auditory evoked potentials carbon monoxide (CO) and nitric oxide (NO) prolonged the latencies of the P_{10} and N_{30} components and increased their amplitude. At high exposure levels the combined effect of CO and NO to N_{30} was overadditive.

In recent experiments the interactions of a substance affecting the cholinergic septo-hippocampal pathway (Ethylcholine Aziridinium, AF64A) with auditory evoked potentials and noise as well as sound induced DC-shifts were studied. In contrast to CO and NO the substance AF64A shortened the latency and reduced the amplitude of auditory evoked potentials.

Biologically meaningful sounds and energy equivalent white noise were used to evoke long lasting DC-shifts. Under the influence of the investigated substance (AF64A) which produces cholinergic lesions similar to Alzheimer's disease, the amplitude of spontaneous EEG was reduced and the noise induced DC-shifts were changed. As main interaction effect a diminution and shortening of noise induced reactions was seen. Moreover under AF64A the differences between meaningful sounds and white noise nearly disappeared.

NOISE AND VIBRATION AS INDICATORS FOR USING EXPERIENCE BASED KNOWLEDGE

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The increasing mechanization and partial automation in machine tool building and, in addition in mechanical engineering, because of noise and vibration control, too, lead to more compact systems consequently, the communication between the skilled worker and the machine increasingly is made more difficult compared with conventional machines.
Therefore, mainly for CNC - machines it is tried to improve process transparency. Feedback by acoustic or vibration informations could be a solution, the investigation and dimensioning of which are subject of this study.
Noise and vibration, in their interaction allow a required extent of communication in the man-machine system, however, from the viewpoint of labour protection and environmental protection are to be restricted to a minimum. Hence, an interesting optimization task is touched.
It is to be taken into acount, that for the operator, noise and vibration are of the same rank when operating a machine.
Based on tested measuring techniques, laboratory and field studies were carried out. It may be concluded that the acoustic and vibrational perception of original process indicators, for the skilled worker do not play the same part during the actual operation programme.
For him, the opportunity would be appropiate to "hear into" or to "feel into" the operating room. The vibration indicator is recorded by the structure-borne sound, as well, and transformed into the area of hearing, is perceivable for the human being
The comparatively short times of exposition, together with efficient measures of noise and vibration control offer the possibility to open the machine's housing for a certain period of time for need of communication, without to contravene safety rules. Appropriate solutions are presented.

RECENT ADVANCES IN THE STUDY OF NOISE ON HUMAN PERFORMANCE

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The present paper will consist of three sections. The first will summarise our knowledge of the effects of noise on performance up to 1988. Recent studies of the effects of noise on performance will then be evaluated within the framework suggested by earlier studies and by methodological criteria. Finally, suggestions will be made regarding areas that warrant further study and the most appropriate methods of examining these issues in the future.

Each section will be organised in the following way. First of all studies examining noise and performance efficiency in the workplace will be considered, then laboratory studies of noise and performance. The importance of the nature of the noise, type of tasks being carried out and characteristics of the person exposed to the noise will also be discussed. In addition, the importance of contextual cognitive factors will be described. Combined effects of noise and other factors will also be reported and consideration will be given to possible mechanisms underlying the various effects of noise on performance.

THE MUNICH AIRPORT NOISE STUDY: PSYCHOLOGICAL, COGNITIVE, AND QUALITY OF LIFE EFFECTS ON CHILDREN

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Abstract

The shutdown of the former Munich International Airport in May 1992 and the inauguration of the current one, have provided an unprecedented opportunity to investigate in a prospective, longitudinal design the psychophysiological, cognitive and quality of life effects of noise exposure on children.

Beginning in the fall of 1991, children were recruited into one experimental and one control group at both the old and new airports. The two experimental groups are comprised of those children who were exposed to high aircraft noise at the old airport, and those who will be exposed at the new airport. The two control groups, one for the former and one for the current airport, were selected from areas that were not and will not be exposed to aircraft noise. The two controls groups were matched to their respective experimental groups at each site on the basis of sociodemographic characteristics.

On two consecutive days 396 children, aged 9 - 11, were tested individually in an air-conditioned and sound attenuated trailer. Measures include overnight urinary catecholamines and cortisol, resting and reactivity measures of cardiovascular functioning, reaction time under noise and quiet conditions, calibrated indices of annoyance to different noise sources, speech discrimination against different noise backgrounds, a Glass and Singer noise aftereffect trace test, short- and long-term memory, visual search, running-memory span, performance on a standardized reading test, perceived noise and environmental quality in the residential setting, and standardized quality of life indices. For the mother, measures were taken on reactivity and resting cardiovascular functioning, reaction time, annoyance scaling and quality of life.

Data analyses for the first measurement wave are currently in progress, and a second measurement wave was finished March 1993. The aim is to follow the same children for at least two additional measurement waves.

VOICE POLLUTION : AUDITORY DISTRACTION AND COGNITION

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Even in a world that has little loud noise, we would still be distracted by sound. Although the effects of loud noise on performance is well established, only recently have we begun to understand the distracting effect of low levels of sound, particularly speech, on human performance. There are very obvious implications for the efficiency of office tasks by "voice pollution". This paper reviews recent developments in the area and sets out some possibilities for future research.

Research has centred upon the effect of an irrelevant sound presented while the person is undertaking a mental task. Usually the task is presented visually so that any disruption cannot be attributed to masking. By varying the nature of the sound and sometimes also by changing the characteristics of the task we may build up a picture of the nature of the disruption. The first point to make is that "distraction" is perhaps a misnomer, since it implies that somehow the sound prevents the registration of information from the task. This is not so since several studies have shown that interference from irrelevant sound does not prevent encoding or registration, rather, it occurs at some later stage. The second point is that early research pointed to the special status of speech in bringing about disruption, the closer a sound approximated speech the greater the likelihood of disruption. Evidence is beginning to emerge that suggests that speech is neither a sufficient nor a necessary condition. Third, the nature and extent of the effect depends very much on the task that the person in undertaking. Effects on memory tasks seem confined to those tasks requiring the retrieval of serial order information. Moreover, although the meaning of the sound makes no difference to the disruption produced on short term recall, if the task is more complex and involves the extraction of meaning such as in the case of proof-reading, then only meaningful sound is disruptive.

Although much more is now understood about the nature of distracting speech, we are some way off a complete account of its effects. For example, there is some evidence that the effect may habituate, but we know little about the circumstances that bring about dishabituation or recovery. Again, our knowledge of performance on complex tasks is rather sparse, with relatively few studies on the effects of reading or comprehension.

EFFECTS ON MENTAL TASKS CAUSED BY BACKGROUND SOUND RECORDED AND PRESENTED VIA AN ARTIFICIAL HEAD SYSTEM

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In the past, the research on the effects of noise on mental performance often revealed ambiguous results. There are experiments that proved noise as deteriorating performance, as well as as improving perfomance, and as a factor of no influence. Most of researchers used artificial sounds as white noise or bandpass noise. Sound pressure level and center frequencies were the mostly used experimental factors. In today's laboratories, however, there is often an excellent equipment to measure and to manipulate sounds. On the other hand, cognitive psychology has developed subtle models on mental processes. Both, the progress of sound measurement techniques and the development of cognitive psychology, lead nowadays to the question, which kind of sound has which influence on which kind of mental process. The irrelevant speech effect on the phonological short-term memory is an excellent example of such a differentiated question. However, the effect of sound on mental performance may also depend on how sound is percepted. In real life situations we are permanently embedded in a world of sound, and our perceptual system has permanently to organize "soundscapes". In order to do that, the binaural hearing system is very important. It makes spatial hearing feasible and facilitates pattern recognition. New techniques, as artificial head systems, allow to record and to present sound with high fidelity, including spatial cues. In our paper we will discuss the importance of spatial hearing concerning the research on noise effects. The results of some preliminary experiments will be presented.

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NOISE-INDUCED HEARING LOSS FROM DAILY OCCUPATIONAL NOISE EXPOSURE; EXTRAPOLATIONS TO OTHER EXPOSURE PATTERNS AND OTHER POPULATIONS

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In ISO 1999 dose-effects relations are presented of hearing damage due to occupational noise exposure. It shows from these relations that an equivalent sound level of 75 dB(A) over an eight-hour working period is, as far as hearing is concerned, the limit of a safe occupational noise exposure. It is concluded that the safe minimum level for the entire 24-hours noise exposure for adults corresponds to an equivalent sound level of 70 dB(A). It is not unlikely that a 5 dB(A) lower level applies to children. The conclusions are based upon observations on:

- the correspondence between asymptotic threshold shift and permanent noise-induced hearing damage;
- damage risk contours for impulse noise, applicable to occupational and environmental noise exposures;
- the extend of noise exposures in present daily life of people in Western society;
- the susceptibility of young children for noise-induced hearing loss.

Since the 24-hours noise exposure of children and teenagers reaches 75 to 77 dB(A) in present Western societies, this implies that their noise exposure may result in some hearing damage. An analysis of available data shows that the hearing of boys and girls until the age of approximately 14 years did not change during the 60's, 70's and early 80's. The results of two quite extensive studies in Austria and Norway indicate a serious deterioration of hearing of young men and women (17/18 years old) in the 80's.

In that respect, a number of noisy activities have been identified as causing hearing damage. They include banging firework, playing in a pop group, listening to pop music in discotheques, during pop concerts and by means of walkmans, listening to loud hi-fi and T.V. equipment, travelling by public transport and using motorbikes and mopeds.

Efficacy of Hearing Conservation Programs; Prediction of NIHL, Remediation.

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The goal of Hearing Conservation Programs (HCP) is to prevent hearing loss, by identifying, monitoring and reducing noise levels; or failing this, to seperate the worker from noise, either by administrative means or by the use of personal hearing protection devices (HPD); to monitor efficacy by regular audiometry; to provide appropriate health education; to enforce management and workforce compliance; and to provide remedial action where necessary.

Noise measurement shoud identify both the absolute workplace sound levels and the hazardous sound experienced by the worker. In the past most emphasis has been placed upon workplace noise levels, rather than individual exposure. Only recently have dosimeters been able to measure total noise exposure plus peak levels throughout a working day. There are still insufficient data available about sound exposures at each ear in various industrial settings: significantly higher exposure levels may be found at ear level than with a body worn microphone and the sound level experienced by the two ears may vary considerably. There is need for accurate binaural toxin exposure measurements in a wide range of workplaces.

Even with many years of experience, the proper methodology of monitoring audiometry is not clear. What type of audiometer is better, manual or self recording? What frequencies should be tested? What step size should be used? There is considerable evidence that the widely used 5db steps are inaccurate and subject to statistical artefact. If this is so, then self recording audiometry using 2.5 or even 1db steps should be adopted.

Classical monitoring audiometry detects damage that has already occured; the identification of a noise susceptible ear is an ellusive goal. Recent work by Murray and LePage suggests that strenght of OAEs reduces in noise exposed workers more quickly than in normals and that this occurs prior to a drop in hearing thresholds. Unduly susceptible ears lose their OAEs more quickly. If verified, this simple test may identify those at undue risk.

There are only few published reports of the long term efficacy of HCPs. There are certain exceptions as the continuing studies from the Dupont corporation, the studies by Royster at al, the comprhensive Provincial study in British Columbia, the large Austrian study, all of which demonstrate benefit. A novel approach has recently been taken by Bertrand in the Quebec mining industry. He obtained noise exposure figures for a variety of workers and, using ISO 1999, determined the expected industry wide hearing loss and compared it with measured losses, demonstrating a 10-15 db protective affect.

In addition to hearing loss, workplace noise prevents the hearing of warning signals; and as Hetu points out, it also makes the workplace an unfriendly environment: noise is tiring, debilitating and prevents easy communication.

For the hearing impaired worker, appropriate rehabilitation should be provided. Current hearing aids are effective with this type of loss, and so are a wide range of other assistive devices, such as telephone and TV amplifiers. A system for providing all of these aids, and of appropriate councilling is mandatory.

INTERPRETING NIHL BY COMPARISON OF NOISE EXPOSED SUBJECTS WITH APPROPRIATE CONTROLS

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It is a truism of medical science that one of the most difficult tasks is to obtain *appropriate* controls. Controls should differ from the test subject in only one respect: the condition that the study aims to examine. In studies of noise-induced hearing loss (NIHL), it has often been necessary to resort to groups of office workers as controls or to use published data on age-associated hearing loss to estimate the hearing status that would have obtained in the test subjects if they had not been exposed to noise. This shortcoming of much past research into NIHL causes severe difficulties of interpretation, because recent studies have shown that extraneous factors such as socioeconomic status (occupational group) can influence group hearing threshold levels materially. Furthermore, studies of groups not exposed to noise and sampled at random from the general population have suggested that otologically normal young subjects have median hearing threshold levels that are closer to 5 dB than the value of 0 dB espoused by ISO 389. Hence, the use of standardized data for control purposes is called into question.

Population studies conducted by the MRC Institute of Hearing Research in the UK have involved noise-exposed individuals, and also individuals not exposed to noise, sampled at random using identical methods. This has enabled statistical control of extraneous variables, leading to a model of NIHL and its dependence on noise exposure. The model predicts hearing threshold levels and their confidence intervals at each audiometric frequency by age and noise exposure for each sex and occupational group. It predicts hearing threshold levels in noise-exposed people that are consistent with previous research; however, because subjects not exposed to noise had poorer hearing than the controls used by many previous studies, the magnitude of NIHL predicted by the model is somewhat smaller than previously thought. Occupational group is significant, with those in manual occupations having poorer hearing than those in non-manual occupations by approximately 3 dB.

ACTUAL EFFECTIVENESS OF HEARING PROTECTION IN HIGH LEVEL IMPULSE NOISE

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ABSTRACT

Current exposure limits for high intensity impulse noise contain factors for hearing protection which are based on very limited data. Recent studies in the U.S. and in France have provided new insights into the protection afforded by hearing protective devices. For impulses with an A-duration of approximately 3.0 ms, protection was found to be adequate for peak pressures up to 190 dB SPL for 6 impulses and 187 dB for 100 impulses. Protection was found to be adequate for 6 impulses with an A-duration of approximately 0.8 ms up to 196 dB SPL. For this A-duration, protection was adequate for 12 impulses up to 190 dB SPL and for 50 and 100 impulses at 187 dB SPL. The hearing protectors used in these studies were earmuffs with perforations in the cushions which provided essentially no attenuation below 500 Hz. In a series of French studies, hearing protection was found to be adequate for impulses produced by a variety of weapons with peak pressures ranging from 165 dB SPL to 180 dB SPL. These included small arms with A-durations less than 1.0 ms, artillery with A-durations of approximately 3.0 ms and other weapons with durations between these extremes. A variety of insert hearing protectors (earplugs) was used in these studies. All had perforations which resulted in poor low frequency attenuation. In both sets of studies, conventional attenuation rating schemes greatly underestimated the actual protection afforded by the hearing protective devices. Direct measurements of the pressures under the earmuff showed these peak levels can be as high as 182 dB SPL without significant effects on hearing.

PREDICTIONS OF NIHL BASED ON ANIMAL STUDIES SPECIES DIFFERENCES AND THEIR IMPLICATION

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Noise-induced hearing loss has been widely studied in various animal species. The physiologic and anatomic consequences of identical overstimulation can be very different from one species to another. For example a pure tone of 1 kHz at 120 dB SPL presented for 12 minutes to the chinchilla induces more threshold shift than the same stimulus presented for 12 hours to the squirrel monkey (Hunter-Duvar and Bredberg, 1974, J. Acoust. Soc. Am., 795-801)! It is difficult to determine the origin of these differences in susceptibility to noise because the experimental conditions are very different from one experiment to another and from one species to another. Therefore, results obtained on animals rarely allow interspecific correlations or extrapolation to the human species (Dancer, 1981, Acustica, 239-246).

We hypothesized that the cochlea exhibits the same resistance to acoustic stress independently of the animal species considered. In that case, the differences observed in the auditory sensitivity of various animal species would essentially originate from the conditions under which the acoustic stimuli are transmitted from the free field to the inner ear. The aim of our study, which was deliberately conducted with a purely mechanical approach, was to determine the physiologic and anatomic consequences of identical acoustic overstimulation in three species of mammals widely used in auditory studies (cat, chinchilla, and guinea pig) and to relate the interspecies differences in noise susceptibility to the characteristics of the peripheral mechanical system (external and middle ear). Our first step was to apply continuous pure-tone overstimulation (2, 4 and 8 kHz) under the same experimental conditions (closed-circuit stimulation, opened bulla, acoustic level measured in front of the tympanum) in all three species. The stimulus was presented during 20 minutes at levels ranging from 80 to 132 dB SPL. The physiologic auditory effects of this overstimulation were evaluated by electrocochleography, and the anatomical alterations of the organ of Corti were assessed by scanning electron microscopy. Our second step was to measure the transfer function of the middle ear in all three species with the help of intracochlear acoustic pressure measurements performed with miniature transducers, and to compare the physiological and anatomical effects of overstimulation as a function of the acoustic input level and acoustic power at the entrance to the cochlea (Décory et al., 1992, in: Noise Induced Hearing Loss, eds. A. Dancer, D. Henderson, R. Salvi and R. Hamernik, Mosby Year Book, 73-88). It was found that for a given input to the cochlea, the interspecies differences in auditory susceptibility are not large between the chinchilla and the guinea pig. However, the cochlea of the cat seems to be more resistant than those of the two other species, by about 6 dB.

The transmission of the acoustic stimulus from the free field to the inner ear seems to be responsible for the largest part of the interspecies differences in auditory susceptibility. This observation is very important if one searchs for the possibility to extrapolate, from the quantitative point of view, NIHL measurements performed on animals to the man and to improve the usefulness of the animal models. Nevertheless, it appears that some cochlear factors (mechanical, anatomical, metabolic, neural...) also contribute to the resistance to noise trauma.

RECENT ADVANCES IN COCHLEAR NEUROBIOLOGY AND NEW CONCEPTS IN ACOUSTIC TRAUMA

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Within the last decade, our knowledge about the cochlear physiology has tremendously progressed. Modern neurobiological approaches of the two types of cochlear receptors have revealed their striking differences both at the transduction and synaptic levels.

Inner hair cells (IHC$_S$) are the real sensory cells which "passively" encode the sensory message and send it to the brain. Conversely, outer hair cells (OHC$_S$) react to sound stimulations by electromotile properties which feed energy back into the basilar membrane. This reverse transduction process gives the cochlea its exquisite properties of sensitivity and frequency selectivity. The innervation and neurochemistry of both types of hair cells are also strikingly different. The neurotransmission between IHC$_S$ and auditory fibers is glutamatergic. The use of glutamate implies fast excitatory properties but also neurotoxic consequences in pathologic conditions such as ischemia and overstimulation. On the other hand, OHC electromotility is regulated by a slow muscular-like motility which is under the control of cholinergic medial efferents.

These findings have several implications in the field of acoustic trauma.

1) The excitotoxicity at the IHC-auditory nerve glutamatergic synapse may prove to be an important factor in noise-induced hearing loss. Actually, the acute and reversit swelling of auditory dendrites after acoustic trauma can partly explain tempora threshold shifts. Similarly, more severe excitotoxic processes, linked to greate exposure to traumatic sounds, may lead to neuronal death and account for part of the permanent threshold shifts. An alteration of the glutamatergic synapse may also be involved in the origin of peripheral tinnitus which occurs after acoustic trauma.

2) All mechanical damage to OHC$_S$ occurring during acoustic trauma would alter the active mechanisms. As a consequence, a survey of these active mechanisms by recording oto-acoustic emissions in subjects exposed to a noisy environment, would provide an objective and accurate testing in the detection of the first OHC damage.

3) Finally, an era of cochlear neuropharmacology is just opening and one could speculate about some clinical applications. For instance, it is possible to envisage a pharmalogical protection against excitotoxicity at IHC level. Similarly, a pharmacological modulation of the OHC efferent control could provide a defensive tool against OHC mechanical trauma.

1 i) CURRENT EXPOSURE STANDARDS; INTERACTION OF EXPOSURES; CRITICAL EXPOSURES; MORPHOLOGY OF TTS AND PTS

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The status of present noise exposure regulations, both national and international, will be briefly reviewed. They are generally overprotective, but this may be necessary in view of the fact that damage to hearing depends not only on workplace noise but also on the noises of everyday life (sociacusis). The problem of how industrial noise, sociacusic noise, nosoacusis and presbyacusis interact--and how they might therefore be separated--has recently received considerable attention, and the question of additivity of these influences will be reviewed. The nature of the "critical exposure" (not critical intensity) in acoustic trauma will be compared in the guinea pig, chinchilla and man. The reduction of hazard due to intermittence will next be discussed. Finally, evidence bearing on the locus of TTS and PTS, based on recent research, will be summarized, and the relation between them examined.

MODELS TO DETERMINE CRITICAL LOADS FOR NOCTURNAL NOISE

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Residents living in streets with high traffic load or in the vicinity of airports suffer from noise-induced sleep disturbances. They claim vehemently for noise abatement and forced extensive research on this problem.

Numerous studies executed so far reveal that sleep disturbances are not only determined by the physical parameters of noise. Instead, they are modified by many non-acoustic variables (experience with the particular noise, age and personality of subjects, etc.). An upper limit, however, which is tolerable with respect to health is not yet determined. This is - above all - related to the uncertainty about the possible pathogenic significance of sleep disturbances which in their turn are not yet unequivocally defined.

But, regarding the people exposed counter-measures must be established now. Due to the limited current knowledge, however, any suggestions are premature and require regular scrutinies and adjustments to the respective state-of-the-art. Tentative decisions are not entirely satisfactory, but noise attenuation of whatever extent reduce the (deleterious) effects even if full protection is not guaranteed.

Upper limits suggested so far consider the number of awakenings as the latter are assumed to be particularly harmful: if they are recalled in the morning they determine subjective sleep quality and may then contribute to psychosomatic alterations and to the development of certain diseases.

Critical loads were elaborated selectively for
- road traffic noise which concerns the majority of noise-exposed people and for
- aircraft noise which evokes - due to its high sound pressure levels - more awakenings than any other noise.

The critical loads suggested for vivid road traffic noise - as deduced from laboratory and field experiments - vary between equivalent sound pressure levels of 37 and 40 dBA.

Human responses to interrmittent noises are rather predicted by the respective maximum levles than by their overall acoustic energy. Many studies were executed with intermittent noise, particularly with aircraft noise. As the critical loads deduced from single studies vary considerably between 45 and 68 dBA it is advisable to pool the results of as much studies as possible. The suggestions based on summarizing evaluations of the literature vary within narrow limits of 53 to 55 dBA.

But even these limits are questioned. In particular, they are regarded as extremely conservative as they are predominantly deduced from laboratory experiments. It is generally assumed that disturbances in the real situation at home are considerably lower.

The paper presents the various models for the determination of critical loads as well as the respective objections and the possible approaches to solve this particular problem.

SOCIAL SURVEYS OF NIGHT-TIME EFFECTS OF AIRCRAFT NOISE

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As part of a wider study of aircraft noise and sleep disturbance, which was mainly concerned with physical monitoring of people's sleep, a social survey was made of 1636 residents near four UK airports. The principal aim was to provide a pool of subjects for the sleep monitoring and a means of sifting them. However, the opportunity was also taken to collect data on general perceptions of aircraft noise and its effects, by day and by night. This allowed comparisons to be made with earlier work, particularly the 1982 UK Aircraft Noise Index Study (ANIS) and social surveys of night noise nuisance carried out at two of the airports in 1980 and 1984.

The questionnaire probed attitudes and reactions to aircraft and their noise. Some questions were aimed at specific night-time factors: sleeping habits, sleep quality assessments and the incidence and perceived causes of disturbance. Others were concerned with personal factors and availability which would affect participation in the sleep monitoring.

Very few respondents described themselves as bad sleepers and, according to their answers, they were roughly evenly divided between deep and light sleepers. Once in bed, between 30% and 45% of respondents reported difficulty getting to sleep, typically on two or three nights a week.

Most people reported being woken from sleep, but this occured 'regularly' in under 20% of cases. Typically, respondents said they were only awakened once per night. Most found it easy to get back to sleep although a significant minority (~25%) found it rather harder. Few were woken up at any particular times of the night although, of those who were, most mentioned midnight to 4am. Aircraft noise was given as a common reason for waking up. However, the main cause cited was being disturbed by partners or own children. Other reasons were noise from traffic and other outside sources and using the toilet. In total, slightly less than 50% of respondents felt refreshed or very refreshed after waking up and 25% felt tired or very tired.

A comparison with the ANIS results showed that the percentages of respondents spontaneously mentioning aircraft noise as a reason for disliking the neighbourhood were in broad agreement. However, residents near to the expanding airport at London Stansted report more awareness of aircraft noise than people with similar daytime noise exposure levels at the other, more established airports. A similar effect emerged when comparing percentages of people 'very much annoyed' by aircraft noise.

Comparisons with the earlier sleep survey results showed that the responses exhibit similar trends, albeit with the large scatter typical of social survey data. The percentages giving aircraft noise as the main reason for having difficulty getting to sleep, for being awakened once asleep and for having difficulty getting back to sleep, once awakened suggested that, in relation to night noise exposure in Leq, general perceptions of nighttime aircraft noise effects changed little between 1980 and 1991.

A multivariate analysis of the results indicates that reported reactions to aircraft noise, both annoyance and sleep disturbance, are influenced by numerous intervening factors, notable amongst which are age, sex, marital status, and whether subjects describe themselves as light or deep sleepers. However, no clear relationships emerge between aircraft noise exposure and reported disturbances, whether known intervening factors (confounding effects) are controlled or not. A trend which appeared to nullify any systematic noise effect is that disturbance and annoyance reactions from two different sites near the same airport tend to be the reverse of what might be expected from their markedly different noise exposures. Further study of this finding could throw important new light on factors which contribute to aircraft noise annoyance.

EEG-BASED RESPONSES TO AIRCRAFT NOISE FOR SUBJECTS SLEEPING AT HOME

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This is a preliminary report on part of a large project to assess the effect of aircraft noise on sleep in residents living near to the four main airports in the UK. 46 paid volunteers (20-70y, 23 male) had their EEG, EOG & EMG recorded for a total of 178 subject-nights in their homes while aircraft noise was recorded in the neighbourhood.

The recordings were made with the Medilog system and subsequent analysis was carried out by automatic computerized sleep stage scoring, all of which was visually checked and edited manually according to accepted criteria. The sensitivity of the scoring for movement time (MT) was increased by reducing the requirement for movement arousals from 50% to 30%. During the recording nights, all aircraft noises (>60 LaMax dB) in the close vicinity were recorded by the CAA(UK). In addition to sleep staging in 30 second epochs, where shifts to W, MT, and stage 1 were of particular interest, detailed inspection of the sleepers EEG response to the aircraft noise event (ANE) was visually investigated for minor arousals. Three categories of minor arousals were developed which were based on movement and EEG arousals. It was important to separate responses evoked by aircraft noise from ongoing background activity. Therefore, in order to control for endogenous arousals any responses noted were compared with a similar period, randomly chosen, between 2 and 5 minutes before ANE`s. A total of 3,149 ANE were analyzed between 22.00 and 08.00 from sleeping subjects.

Detailed inspection of the EEG data revealed that 14.4% of the ANE produced some type of response ie. either major or minor arousals while 10.3% was estimated to be due to background endogenous arousals. This could be interpreted as 4.1% of ANE or 1 aircraft noise in 24 causes some response in the EEG.

Major arousals (shifts to W & MT) occurred much less frequently, with 4.17% of ANE and a background of 4.15%. This suggests that only 0.02% of ANE cause a major arousal in the EEG. The main type of responses which made up most of the 4.1% were shifts to stage 1 and minor arousals (< 3seconds).

There was clear evidence of biological variation in inherent arousals which affects the responsitivity of individuals. If there had been an endogenous arousal 2-5 mins before an ANE then the individual was twice as likely to respond to that ANE.

Therefore, ANE do cause detectable changes in the EEG of residents sleeping at home but these changes are mainly restricted to a lightening in the depth of sleep (shifts to stage 1) or brief arousals that do not lead to awakening. Furthermore, a response was more likely if there had been an endogenous arousal within 5 minutes before the ANE.

A FIELD STUDY ON THE EFFECTS OF AIRCRAFT NOISE ON ACTIMETRICALLY AND SUBJECTIVELY MONITORED SLEEP

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This field study assessed the effects of nighttime aircraft noise on actimetrically measured sleep in 400 people (211 women, 189 men, aged 20 - 70 y; one per household) habitually living at one of eight sites adjacent to four UK main airports, with different levels of night flying. Subjects wore wrist-actimeters for 15 nights, and completed morning sleep logs. A sample of 178 nights of sleep EEGs were recorded synchronously with actigrams. The EEG was used to develop filters for the raw actigrams, in order to: (i) estimate sleep onset; (ii) compare actigrams with aircraft noise events (ANEs). Actigrams filtered to detect the onset of discrete movements were, for example, able to detect 88% of all EEG determined periods of interim wakefulness of >15 sec and periods of movement time of >10 sec. General findings (other than ANE effects) with actimetry were: (a) an increase in discrete movements as sleep progressed; (b) an ultradian rhythm in these movements, even when all actimetry nights (>4.5 million epochs of data) were superimposed on one other; (c) men had significantly more discrete movements than had women. With regard to ANEs: (1) actimetry and self reports showed that only a minority of ANEs affected sleep, and, for most of our subjects, that domestic and idiosyncratic factors had much greater effects; (2) despite large between-site variations in ANEs, the difference between sites in overall sleep disturbance was not significant; (3) the likelihood of an actimetric response to an ANE also followed a rhythmicity which appeared to depend on the phenomenology of sleep, possibly SWS and REM sleep; (4) there was a diminished actimetric response to ANEs in the first hour of sleep, and, apparently, also in the last hour of sleep; (5) men were more likely to respond to ANEs.

ENVIRONMENTAL NOISE DURING SLEEP AND SYMPATHETIC AROUSAL ASSESSED BY URINARY CATECHOLAMINES

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Sleep is accompanied by a reduction of heart rate, blood pressure, and frequency and grade of ventricular premature beats, as well as lengthening of the electrocardiographic Q-T interval. These changes have been attributed to sympathetic nervous withdrawal and/or increase in parasympathetic tone. The frequency of onset of acute myocardial infarction is lowest during sleep.

Noise during sleep causes arousals and changes in sleep stage. Some data also suggest that increases in heart rate occur due to noise, even after many years of exposure. Abnormal heart rhythms may also occur in response to noise during sleep in susceptible individuals, such as those with congenitally long Q-T intervals.

Noradrenaline (NA) is the main sympathetic neurotransmitter in the heart. Much of it is removed from circulation by re-uptake by the sympathetic nerves, but spillover into the blood is proportional to cardiac sympathetic nervous firing rate. Adrenaline (ADR) is primarily an adrenal medullary hormone which affects heart function. NA release in the heart and the secretion rate of ADR are susceptible to mental challenge, even by relatively mild stressors. All catecholamines released in the body not subject to re-uptake are ultimately excreted in the urine in their native form or as metabolites. Extreme secretions of catecholamines can damage the heart directly or indirectly, but little or nothing is known of the effects of moderate but chronic elevations of catecholamines during resting states such as sleep.

We studied the effect of recorded aircraft and truck noise on arousals and overnight urinary catecholamines. The subjects were nine hospital outpatients (mean age 58 years) who had presented with a history of cardiac arrhythmia. They slept in a hospital laboratory for four non-consecutive nights. Sleep stage was monitored continuously using EMG, EOG, and EEG (vertex) electrodes. The first night was used for familiarisation. The other three consisted of one 'quiet', and two 'noise' nights (truck and aircraft noise respectively), in counterbalanced order. Fifty aircraft or truck noises, at levels of 65 to 72 dBA peak, average durations 24 sec. (AC) and 17.8 sec. (TN), were used on each 'noise' night. Intervals between noise presentations were randomised, and ranged from 3 to 20 min. Subjects voided before retiring. All urine subsequently passed was saved, including a final collection in the morning. The urine was assayed for noradrenaline, adrenaline and dopamine, by high pressure liquid chromatography.

Sleep polygraphs indicated that 53% of the noises presented during sleep were followed by arousals (appearance of alpha frequency in the EEG), while only 10% of paired quiet intervals of the same duration showed alpha responses. However, statistical analyses of the overnight noradrenaline, adrenaline, and dopamine assays from 'noise' and 'quiet' nights indicated no effect of noise ($p > .05$), for any or all of the three catecholamines.

These data suggest that exposure to significant transportation noise during sleep is not an additional source of risk for the cardiovascular system in terms of altered sympathetic drive, despite considerable enhancement of arousals and changes in sleep stage. However, recent work has shown that the spillover of catecholamines such as noradrenaline in different regions of the body may vary greatly due to differing sympathetic nerve firing rates in particular organs such as the heart. Also, while overnight urinary catecholamines are more reliable measures of the total sympathetic nervous activity overnight, serum catecholamines sampled at locations specific to the heart (eg coronary sinus) within one minute of the noise onset would be better indicators of 'surges' or peaks in catecholamine levels in those locations. Further work is necessary to determine the effects of noise on regional (heart) spillover of catecholamines and whether intermittent noise and associated arousals are accompanied by brief surges of catecholamines in the blood serum.

RESEARCH ON NOISE AND SLEEP : PRESENT STATE

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Investigations of the effects of noise on sleep have focussed to a great extent on *primary effects* during the sleep, such as changes in EEG and heart rate. In later years, studies have also been performed on different *after-effects*, such as subjective sleep quality, performance and psycho-social wellbeing. Little attention has been paid, however, to effects of noise on the time needed to fall asleep.

Effects of noise on time to fall asleep is considered as an important aspect of noise-induced sleep disturbances by the exposed individual. Different studies with noise levels from 45 dBA peak level, show an increase of 7 to 15 minutes in the time to fall asleep. The number of events and the difference between background and peak level seem to be more important than the absolute peak level for these type of effects.

Effects of noise during sleep in terms of *cardiac responses* occur at very low peak noise levels, 32 dBA (Vallet et al 1988). Concerning other acute reactions, such as *body movements*, recent studies show no difference in the reactions to 40, 50 or 60 dBA maximum noise levels. A three-fold increase in number of body movements at all three noise levels was found at 16 events per night, and a slightly lower increase (two-fold) at 64 events per night as compared to quiet periods of the night. Concerning *awakening effects*, Griefahn (1990) proposed limits for noise emissions for irregular noise during the night in terms of the number of noises and maximum noise levels. At levels below 54 maximum noise level, the number of events per night was considered irrelevant for awakening effects. Recently Terzano et al (1990) has found an increase in modifications of the sleep structure in terms of periods of arousal fluctuation with increasing noise levels. An interesting and new finding was that these sleep modifications were also significantly correlated with the personal evaluation of sleep quality.

After effects of noise-disturbed sleep : More recent studies indicate effects in terms of reduced *subjective sleep quality* after exposure to 45 dBA maximum noise levels among *noise-sensitive* persons (Öhrström et al 1991). This group of "rather or very noise sensitive" has been shown to include about 1/3 of the general population. At 32 noise events per night, the sleep quality was reduced by 9%, and at 128 noise events the reduction was 19% as compared to quiet control nights. A maximum noise level of 45 dBA also caused increased *tiredness during the day*. Concerning more long term effects of noise-disturbed sleep, further evidence is now available in the litterature that noise disturbed sleep may also effect *psycho-social wellbeing*.

THE INFLUENCE OF NIGHT-FLIGHT NOISE ON SLEEP: CHANGES IN SLEEP STAGES AND INCREASED CATECHOLAMINE SECRETION

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The effects of aircraft noise on sleep were studied on 40 healthy adult subjects during 200 experimental nigths in a sleep laboratory. The subjects lived in the vicinity of an airport thus they were exposed to day-time aircraft noise.

The following two factors were varied:

1) The number of flights per night (16, 32, 64 flights with a maximum indoor sound level of L_{max} = 75 dB(A) resp. no flights for the control group).
2) The temporal distribution of the flights during the sleeping time (five variations).

In order to determine the sleep stages and the awakening reactions the electrophysiological data EEG, EOG and EMG were recorded for each subject and for each night. The potential inter-relationship with day-time noise exposure, personality traits and general day-to-day conditions were reflected upon as control variables.
The group participating in the experiment without noise exposure (control group) spent a second week (5 nights) in the sleep laboratory, exposed to various sound conditions (16, 32 and 64 flights with an indoor sound level of L_{max} = 75 dB(A) and 64 flights with L_{max} = 55 dB(A) and 65 dB(A)).
In addition to the electrophysiological data, the secretion of catecholamines (adrenaline, noradrenaline) was measured after each night during two experimental weeks.

The study reveals that night-flight noise (16 to 64 flights per night with L_{max} = 75 dB(A)) leads to an irregular increase of awakening reactions and to a distinct change of the sleep stage distribution.
A significant decrease of the sleep quality can be observed at an indoor sound level of 55 dB(A) and 64 flights per night (L_{eq} = 36 dB(A)).
The adrenaline secretion is under noisy condition significantly higher. The increase of adrenaline secretion can be observed at an indoor sound level of 55 dB(A) and 64 flights per night.

In addition, an inter-relationship analysis shows a close link between adrenaline secretion and the sleep stage distribution. The catecholamine secretion increases with the sound level and presumable with the number of flight events.

The temporal pattern of the nocturnal fligths affects the sleep stage distribution as well. As the most modified distribution of sleep stages entails elements of improved as well as decreased sleep quality any assessment becomes difficult.

Furthermore, it may be possible to present the first findings about catecholamine secretion under night-flight noise of a field study finished May 1993.

NOISE DURING DAYTIME SLEEP : EEG DISTURBANCES IN SHIFTWORKERS

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Traffic noises are known to induce significant modifications of global sleep EEG structure. They are even more deleterious when they occur in a period of the nycthemere where the organism is less resistant to stress. It is the case for the shiftworker daytime sleep which is exposed to the daytime noise.

EEG response to noise was analysed during night-time and daytime sleep in shiftworkers. These responses allowed us to study the variability of the sensitivity to noise with regard to the nycthemeral placement of sleep and the electroencephalographical context of noise occurence.

The experimental program was constituted of 4 recording sessions ; 14 shiftworkers of the food industry performed an "habituation daytime sleep", two "experimental daytime sleep", and one "experimental night sleep".

These sessions were dispatched during a three weeks shiftwork system. The 3 daytime sessions took place during the 1st week (nightshift: 2200 to 0600), on Tuesday, Thursday and Friday, respectively (sleep ad libitum from 0800). The night-time sleep was recorded during the 3rd week (morning shift: 0600 to 1400) on Thursday-Friday night, from 2200 to 0400. During night-time and daytime sessions three types of traffic noise were delivered: Truck (71 dB(A)), Motorbike (67 dB(A)) and Car (61 bB(A)) emerging from a background noise (filtered pink noise) of 35 dB(A). The noises were semi-randomly distributed at a rate of 9 per hour [L_{eq} of 49 dB(A)].

We focused on three types of EEG responses: the "Phase d'Activation Transitoire" (PAT) (Schieber et al. 1971), the Sleep Stage Change (SSC) and the Awakening (AW). A special attention was taken to characterize the relationships between these responses and the presence of concomitant slow wave background. A noise was considered to be synchronous to slow wave background in NREM sleep (stages 2,3 and 4 sleep), when slow waves were present at least 5 s before the noise peak level

The results show that, compared to night-time sleep, there was some modifications in daytime sleep structure: increase of SWS (especially sleep stage 4), decrease of REM cycle duration and of stage 2 and REM latencies and, lastly, earlier SWS and REM barycenters.

Motorbike noise produced more PATs, SSC and AW than the other noises during daytime sleep although it was not the loudest. These effects were less clear cut during night-time sleep. The Car noise remained the less disturbing one.

During night-time and daytime sleep, noises induced more PATs, SSC and PAT+SSC association in NREM sleep (sleep stages 2, 3 and 4) than in REM sleep. On the opposite the percentage of isolated PATs provoked by noise (PATs without any other EEG event) was higher in REM sleep than in NREM sleep. This last result suggest the need to partition PAT in, at least, two classes. Daytime REM sleep was more disturbed by noise than the night-time one, as more EEG events and SSC were induced in this state.

During night-time and daytime NREM sleep, noises occuring within a slow wave background produced less PATs and AW than noises occuring without slow wave background. Nevertheless, the noises occurring during slow wave background provoked the same percentage of EEG response during daytime and night-time NREM sleep. So the changes occurring between daytime and night-time slow waves appeared to be more quantitative than qualitative

In conclusion, reactivity to noise during sleep depends not only on the sleep stage and type of noise, but also on the period of the day where sleep is taken and of the EEG background where the noise occurs.

Schieber JP, Muzet A, Ferriere PJR. Les phases d'activations transitoires spontanées au cours du sommeil normal chez l'homme. *Arch Sci Physiol* 1971; 25: 443-465.

AIRCRAFT NOISE AND SLEEP DISTURBANCE: A UK FIELD STUDY

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Current restrictions on night flights at London's airports were based, in part, on the results of social survey studies carried out more than 10 years ago. During 1991, a major field study was carried out by a CAA/university team to obtain more objective measurements of the effects of aircraft noise on the sleep of people in their homes near four UK airports. Most measurements were made using wrist actimeters although the methodology was validated via simultaneous sleep-EEGs from a sample of the actimetry subjects. The details of the experimental work are described in a number of companion papers. This paper describes the aims of the study, the scope of the experimental work and the main findings.

The aims were to determine the relationships between outdoor aircraft noise levels and the probability of sleep disturbance, and the variation of these relationships with time of night. To meet these, it was also necessary to investigate the influence of non-acoustical factors upon disturbance of people's sleep including their age, sex and personal characteristics, their general views about the neighbourhood, their perceptions about sleep quality and the ways in which this might be affected by aircraft noise.

Volunteer subjects were recruited from 8 study areas. The sites were chosen to cover a wide range of nighttime aircraft noise exposures (Leq) and widely different combinations of event noise levels and numbers. At each site, 200 people were interviewed in a preliminary social survey. From the respondents at each site, 50 participants were selected who met various sampling and test criteria. At each site, all 50 subjects wore actimeters for a fifteen night monitoring period; 6 of them underwent simultaneous EEG monitoring on four sequential nights.

In all, 400 subjects were monitored for a total of 5742 subject-nights. Sleep-EEG were obtained from 46 subjects for 178 subject-nights. In total, some 40,000 subject-hours of sleep data were analysed. A total of 4823 separate aircraft noise events were measured during the 120 measurement nights at outdoor noise levels from 60 dB(A) to more than 100 dB(A) Lmax.

Actimetry was found to be a convenient and valid technique for investigating sleep disturbance in the home. For the EEG-sample, the agreement between actimetrically determined disturbances and EEG-measured awakenings was good: 88% of all awakenings matched actimetric disturbances. The agreement in the case of undisturbed epochs is even higher, 97% overall. About 40% of the actimetric disturbances represented awakenings of 10-15 seconds or more. The remainder were lesser perturbations.

The study revealed that, once asleep, very few people living near airports are at risk of any substantial sleep disturbance due to aircraft noise, even at the highest event noise levels. At outdoor event levels below 90 dBA SEL (80 dBA Lmax), average sleep disturbance rates are unlikely to be affected by aircraft noise. At higher levels, the chance of the average person being wakened is about 1 in 75. This probability indicates that even large numbers of noisy nighttime aircraft movements will cause very little increase in the total awakenings, which, for the average subject, numbered about 18 per night.

However, variations about the average are substantial; the most susceptible people 2-3% of people are over 60% more sensitive than average; some may be twice as sensitive to noise disturbance. Also, men were disturbed from sleep about 15% more frequently than women. Time of night and time from sleep onset are also significant factors. People appear to be most resistant to disturbance after first falling asleep; the overall disturbance rate then increases steadily, from the equivalent of about two awakenings an hour at the beginning of the night to about three per hour at the end of the night.

EFFECTS OF LOW LEVELS FROM ROAD TRAFFIC NOISE DURING NIGHT - A LABORATORRY STUDY ON NUMBER OF EVENTS, MAXIMUM NOISE LEVELS AND NOISE SENSITIVITY.

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AIM

A laboratory study was performed to elucidate the importance of the number of noise events with relatively low maximum noise levels for sleep disturbance effects (body movements, subjective sleep quality, mood and performance). Comparisons were also made with earlier experiments with maximum noise levels of 50 and 60 dBA.

METHOD

Twelve test persons slept eight nights under home-like laboratory settings. During four of these nights, they were exposed to 16, 32, 64 and 128 noise events from recorded road traffic noise at a maximum noise level of 45 dBA. All test persons (aged 20 to 42 years) considered themselves rather or very sensitive towards noise.

RESULTS

The results showed a significant decrease in subjective sleep quality at 32 noise events per night. At 64 noise events (Leq=25.2), 50 % of the test persons experienced difficulties in falling asleep and, as compared with quiet nights, the time required to fall asleep was on average 12 minutes longer. The occurrence of body movements was significantly related to reported number of awakenings, and the number of body movements were three times higher during the noisy periods of the night as compared with the quiet periods, indicating acute noise effects. The results of a vigilance test indicate that noise during the night might prolong the time needed to solve the test. Finally, a tendency towards lower mood was seen after nights with noise exposure.

GENERAL DEVELOPMENTS IN COMMUNITY RESPONSE RESEARCH

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During the past five years community response research has flourished in many countries, especially in Western Europe and Japan. This is reflected by the over 60 contributions from this field of research at this congress. Obviously, we had to structure this large number of contributions, and we did so by identifying the major developments during the past five years. Some major developments are reflected in the choice of the invited papers. These invited papers address the issues of: the role of ambient noise in evaluating a target noise; the social impact of noise prevention and reduction measures; response functions for environmental noise (relating to the question: is all noise the same?); and penalties for impulsive noise.
Other developments appear from the clustering of mutually related free contributions. Unfortunately, the multitude of free communications made it impossible to grant all authors sufficient time to give an oral presentation. Therefore it was decided that all free communications would be presented as posters. Free communications relating to major developments were selected for short oral presentations, introducing the corresponding posters. Selected clusters are: reactions to changes in noise environments; annoyance in non-residential settings; evaluation of alternative noise descriptors, impact of non-acoustical parameters on annoyance; and evaluating the response to impulse noise. The contributions in the clusters will be reviewed by discussants, who, as I hope, will trigger stimulating discussions to complete these 'mini-sessions'.
You are all invited to visit the posters and vividly communicate with the authors.

Pendant les dernières cinq années, la recherche sur la réponse de la communauté au bruit s'est proliférée dans plusieurs pays, surtout l'Europe de l'Ouest et le Japon. Ceci est reflété dans plus de 60 contributions dans ce domaine de recherche à ce congrès. Nous avons dû structurer ces nombreuses contributions en identifiant les thèmes majeurs de ces dernières années. Quelques développements majeurs sont reflétés dans le choix des contributions invitées. Les contributions invitées concernent: le rôle du bruit ambiant pour évaluer un bruit spécifique; l'impact social de la prévention du bruit et des mesures de réduction; des fonctions de réponse pour le bruit de l'environnement (en ce qui concerne la question: tout les bruit ont-ils le même effet?); et les pénalisations pour le bruit impulsif.
D'autres développements apparaissent dans les groupes de contributions libres. Malheureusement leur grand nombre ne permet pas une presentation orale par tous les auteurs. C'est pour cela qu'il a été décidé que toutes les contributions libres seraient présentées comme des posters. Des contributions libres concernant des développements majeurs ont été sélectionnées pour des présentations orales courtes, comme introduction pour les posters correspondants. Les groupements sélectionnés sont: les réactions aux changements de bruits dans l'environnement; la gêne dans des environnements non-residentiels; une évaluation des descripteurs alternatifs du bruit, l'impact des paramètres non-acoustiques sur la gêne; et l'évaluation de la réponse au bruit impulsif. Les contributions dans les groupements seront évaluées par des discuteurs, qui, ce que j'espère, commenceront des discussions stimulantes pour conclure les 'mini-sessions'.
Vous êtes tous invités à visiter les posters et à communiquer vivement avec les auteurs.

THEORIES AND EVIDENCE ON THE EFFECT OF AMBIENT NOISE ON REACTIONS TO MAJOR NOISE SOURCES

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This paper reviews seven theories and the evidence from more than 20 studies about the relationship between residents' annoyance with a major noise source and the acoustical context in which that noise is experienced. These theories are derived from one of three sources: empirical observations of acoustical phenomena, normative assumptions about residents' values, or theories about the relativity of nuisance judgements.

The best available evidence on these hypotheses comes from more than 20 surveys of residents' reactions to aircraft and other noise under varying ambient noise conditions. The balance of this evidence indicates that ambient noise in residential areas has no important impact on target noise annoyance in these studies. The evidence supports the conclusion even after some adjustments are made for variations in sample sizes, quality of survey evidence, quality of noise information, type of target noise and method of analyzing the data. The balance of the existing evidence thus supports the independent judgement hypothesis that residents' annoyance with a noise is independent of the ambient noise level. The findings and theories in this paper concern residents' personal feelings about noise, not their complaints to authorities or their other public actions.

The present findings are inconclusive in the following respects: (1) there is almost no information about reactions in remote areas with ambient noise levels of less than 40 dB (L_{Aeq}), (2) there are large, unexplained differences between the findings in different locations, (3) there are important methodological weaknesses in most of the studies, and (4) the information about the acoustical environment is quite limited (for example, there is usually information about the Equivalent Continuous Sound Level but not about the extent to which the rated noise sources were inaudible). Carefully designed research at large numbers of locations in strategically specified noise environments could be expected to provide better evidence about the impact of ambient noise.

THÉORIES ET ÉVIDENCE SUR L'EFFET DE BRUIT ENVIRONNANTE SUR LES RÉACTIONS À PROPOS D'UNE SOURCE DE BRUIT GRAVE

Cet article évalue sept théories et l'évidence de plus que vingt études concernant la relation entre nuisance des zônes d'habitations par une source de bruit grave et le contexte acoustique où on éprouve ce bruit. On a identifiqués trois principes d'où on peut dériver ces hypotheses: acoustique, normatif et l'environment. Les meilleures preuves disponibles de plus que vingt revues des réactions des habitants à propos des avions et autre bruit sous des conditions de bruit environnante differents indiquent que le bruit environnant dans des régions habitants n'a pas une influence importante dans l'objectif de bruit nuisance dans ces études. Les résultats présents sont limités par l'extense des environs de bruit qu'on a etudié et la défiance des methodes d'étude.

A REVIEW OF PENALTY FOR IMPULSIVE NOISE

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Both in the field and in the laboratory, it has been shown that for single sources annoyance is well predicted by the equivalent sound-pressure level, Leq. This does not mean, however, that road-traffic, aircraft, and shooting sounds with the same Leq are also equally annoying. In the method of rating sounds with respect to the expected community response, the difference in dose-response functions may be accounted for by adding level-dependent corrections or penalties. In general, these penalties are computed relative to the dose-response relationship for road-traffic sounds. The penalty for a specific environmental sound has to be added to its Leq to find the Leq of the equally annoying road-traffic sound.

The present paper will be mainly concerned with the dose-response functions for impulse sounds produced by small and large firearms. Results from field and laboratory studies already reported in the literature will be supplemented with recently obtained results. It will be shown that in several occasions sigmoid shaped curves may be preferred to linear functions. While for impulse sounds produced by small firearms, the relevance of a level-dependent penalty is beyond any doubt, the present results indicate that for large firearms the application of a penalty may be avoided if the Leq of the impulses is C-weighted instead of A-weighted.

Furthermore, existing differences between dose-response relationships of impulse and more continuous road-traffic sounds will be related to basic psycho-acoustic phenomena such as the frequency dependent sensitivity of our hearing system, which depends on sound level as well, and loudness recruitment. Finally, the role of the level-dependent penalty in the prediction of total noise annoyance in conditions with the combined noise sources will be discussed.

RESPONSE FUNCTIONS FOR ENVIRONMENTAL NOISE

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Particularly since Schultz published his synthesized single curve as the best currently available estimate of public annoyance due to transportation noise of all kinds (in JASA, 1978), there has been an intense debate about the dose - response curves for environmental noise. Here results are reported from a study which addresses that issue. The original data from a number of European studies were compiled. To find the response functions, these compiled original data were re-analyzed at the individual level. Much effort has been put into a comparable determination of the exposure measures and the effect measures for different studies.
Dose - response functions are presented for different sources of transportation noise (aircraft, highway, other road traffic, railway) and for impulse noise. It was found that, at the same L_{dn}, aircraft and highway noise are more annoying than other road traffic noise, which in turn was found to be more annoying than railway noise (trains, trams). The impulse noise level at which people start to report annoyance is considerably lower than the 'threshold' for transportation sources and, especially at low levels, impulse noise is more annoying than any transportation noise.
These results are related to the discussion initiated by Schultz about response functions for environmental noise. Our curve for the percentage highly annoyed for road traffic (not highway) approximately coincides with Schultz' single curve. Our finding that the curve for aircraft lies above the road traffic curve, which in turn lies above the curve for railway noise ('above' means more highly annoyed at the same L_{dn}) supports Kryter's conclusion (in JASA, 1982) that, at the same L_{dn}, aircraft noise is more annoying than noise from ground vehicles. Kryter argued that this conclusion was already suggested by the data considered by Schultz. For highway noise, however, we found a curve for the percentage highly annoyed that is close the curve for aircraft. All together it appears that neither a single curve (Schultz) nor two separate curves (Kryter), for aircraft and ground vehicles, suffice to give an adequate representation of the data for transportation noise.
The implications of these results for the formulation of consistent health limits in terms of dose measures, such as L_{dn}, are pointed out. Based on the response functions, equally annoying exposure classes are defined for different sources.
Also the limitations are discussed of norms that are formulated in terms of such dose measures. These limitations are related to limitations with respect to the range of application of the dose - response functions on which they are based. Special features, such as sqealing of trams in curves with a short radius, cause departures from the above dose - response functions, in this case for railway noise. And, especially around many factories, incidental sounds appear to be a significant determinant of the annoyance. Their contribution to the annoyance is likely to be greater than would be expected from their contribution to dose measures, such as L_{dn}. The formulation of criteria for such situations is discussed.

THE SOCIAL IMPACT OF NOISE PREVENTION AND REDUCTION MEASURES

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For almost 15 years a large number of industrialised nations have been applying regulations or legislations which aim to protect populations from noise when new transportation infrastructures are created. Depending on the country concerned, the maximum authorised daytime Leq is usually in the 60 to 65 dB(A) range. Guidelines for blackspot correction usually consider that action should be taken when daytime Leq exceeds 70 dB(A).

Initially, the situations adopted consisted in erecting noise barriers and noise embankments along roads and railway lines in suburbs and rural areas. In urban environments the solution adopted most frequently was to soundproof the facades of the most exposed buildings. More recently other measures have been adopted such as the use of low-noise road surfaces and the limitation of traffic speeds (e.g. Tempo 30 in Germany and Zone 30 in France).

These measures have not only had a significant effect on reducing noise levels by from 3 dB (low-noise road surfaces) to 20 dB (soundproofing the facades of buildings) but an extremely significant social impact. Social surveys of the perception and satisfaction of populations protected from noise reveal a wide range of positive impacts of such measures on communities.

Often, the primary effect sought is to reduce overall or behavioural annoyance and thus improve disturbed domestic activities such as sleep, watching T.V., conversation, etc. The effect of corrective action does, however, depend on a wide range of parameters which are either directly related to noise (decrease in noise levels, modification of the frequency spectrum), or to psycho-sociological factors.

Positive induced or secondary effects can also be observed, for example the reutilization and thus the revalorization of housing and adjacent outdoor spaces - gardens, playgrounds and leisure areas - revitalization of social relationships between the inhabitants in protected zones, reduction in air pollution and dust entering the homes from outdoors and energy savings (in the case of improved soundproofing), a feeling of enhanced security when a noise barrier is located between buildings and roadways.

These positive effects could be nevertheless counterbalanced by negative induced effects such as emergence of noise from other source[illegible]h had previously been hidden (in particular noise from neighbours inside and outside buildin[illegible] lack of soundproofing of outdoor spaces when homes have been insulated, the visual intrusion and the appearance of noise barriers, particularly in rural areas.

The wide diversity of effects raises questions about the methods used to evaluate the effectiveness of noise abatement prevention and reduction measures. The somewhat limited single criterion approach in terms of "forecast noise level reductions" should now be combined with a multi-criteria approach to evaluate these effects. Although only in the development phase at this time, this combined approach can be particularly effective in situations in which there is a significant decrease in annoyance due to a relatively small decrease of noise levels.

A research programme to investigate and develop this approach could be of interest as it would provide pertinent and complete information for decision-makers.

ACOUSTIC REFLEX FEATURES AND NOISE DAMAGE TO THE EAR

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Two aspects of the acoustic reflex (AR) are particularly interesting in relation to the noise effect on the ear: a) its protective effects and possible implications for predicting degree of susceptibility; b) AR features, e.g. shifts of AR threshold, may give important information of the degree and type of temporary and permanent noise damage to the ear.

The activation of the AR leads to an increase of middle-ear stiffness and probably also to a mechanical decoupling at highest contraction strength. The result is an attenuation of transmission of low-frequency sounds. The stronger the contraction the larger the attenuation and the more it extends towards high frequencies. The time course of the AR response has two features which lessens the total attenuative capacity of the AR: the relatively slow onset and the tendency to decay during constant sound stimulation. The consequences for these limitations for the protection provided by the AR against NIPTS should, however, not be exaggerated. In many hazardous noisy situations, the sound is time varying - counteracting the fatigue - and many short impulsive sounds occur in bursts - making the repetition rate and the relaxation of reflex response more crucial features than the onset latency. These questions will be treated on the basis of human and animal studies. The results show that the AR does protect the ear in time-varying industrial noise and that it does protect against impulsive noise provided the reflex is activated with high repetition rate or an added protective sound.

The second question has been investigated in experiments in rabbits, where we have compared the shift of auditory threshold (assessed as detection threshold of auditory brainstem response) and the AR threshold, and related the shifts to the type of exposure and the relative contribution of inner and outer hair-cell damage. The results showed that short-term high-level noise exposure gave more inner hair-cell damage than the same noise energy presented at low level for long time. The latter condition gave more outer hair-cell damage.

In the corresponding animals, the acoustic reflex threshold was raised in cases with inner hair-cell damage, but unchanged or lowered in cases with outer hair-cell damage. It is hypothetized that these AR threshold changes relate to a large extent to shifts of the tails of the frequency tuning curves of the single auditory-nerve fibers.

In conclusion: a) The AR has a capacity to protect against continuous as well as time-varying and impulsive sounds provided the muscle is strongly activated; so far, individual susceptibility has not been possible to assess preexposure on the basis of AR recordings. b) The shift of AR threshold occurring after noise is primarily associated with an inner hair-cell lesion and thus, extends the characterization of the noise damage provided by auditory threshold determinations.

PROTECTION FROM NOISE-INDUCED HEARING LOSS BY PRE-EXPOSURE TO NOISE

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Despite over 100 years of experimental research, our understanding of the mechanisms underlying noise trauma, or the means of protecting against noise trauma, needs to be clarified. One of the most intriguing observations in noise research concerns the auditory systems capacity to modulate the adverse affects of acoustic overstimulation. A better understanding of the means of modulating these affects would help to elucidate the relationship between permanent and temporary hearing losses. At present, the underlying mechanism that distinguishes a temporary hearing loss from a permanent hearing loss is not known.

We have shown previously that the damaging effects of noise could be modulated by "training" or sound conditioning guinea pigs to a long term, low level acoustic stimulus prior to a traumatizing exposure. The "trained" group were exposed continuously to a 1kHz tone at 81dB SPL, for 24 days prior to being exposed to the traumatizing tone (1kHz, 105 dB SPL, 72 hours). The control group were exposed only to the traumatizing tone. The salient findings of this study was that sound conditioning results in 1) a 20 dB reduction of the auditory brainstem response relative to animals not "trained", and 2) complete recovery of auditory sensitivity after one month. The control group continued to show a threshold shift of approximately 25 dB. These findings are not particular to the guinea pig since recent results from this laboratory indicate that the rabbit responds to sound conditioning in a similar fashion.

The mechanism by which sound conditioning can modulate the sensitivity of the auditory system to acoustic overstimulation remains unknown. In pursuit of better understanding the underlying mechanism we have extended our methods of study to include the measurement of otoacoustic distortion product emissions, forward masked tuning curves and a morphological analysis of the cochlea, the stapedius muscle, and the cochlear nucleus. Results from these studies will be presented and discussed.

POSSIBLE PHYSIOLOGICAL CHANGES UNDERLYING THE NOISE-INDUCED TOUGHENING EFFECT

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Reports by several laboratories, using different species show that the auditory system can be made more resistant to the effects of noise by prior exposure to moderate levels of noise. This increased resistance is manifested as either decreased amounts of temporary threshold shift (TTS) with repeated exposures (reduction of up to 30 dB) or less permanent threshold (PTS) with exposure to high level, traumatizing noise (10 to 20 dB less than control group). This paper reviews these three sets of experiments on possible biological changes that might account for the increased resistance. First, studies of chinchillas with ablated stapedius show that, compared to intact animals, the subjects develop more TTS during a series of repeated exposures. However, the subjects with ablated stapedius and a history of repeated exposure suffer less PTS in future exposures with higher level noise. In a second series of experiments, chinchillas had the cross efferent system sectioned. During 10 days of intermittent exposures, low frequencies (.5, 1 and 2), developed progressively less TTS, while TTS at the higher frequencies (4 and 8 kHz) there was no change during the 10 days of experiments. These results suggest the efferent system may play a role in toughening at high frequency, but is irrelevant at lower frequencies. Finally, studies of Distortion Product Otoacoustic Emissions (DPOAE) show that the DPOAE are maximally depressed during the beginning of a series of 10 day intermittent exposure, but recover faster than thresholds during the 10 days. These results will be discussed in terms of changes to the outer hair cells. Research supported by a NIH R01 DC01237-02.

COCHLEAR EFFERENTS AND ACOUSTIC TRAUMA

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The Organ of Corti possesses two types of hair cells: the inner (IHCs) and the outer (OHCs). The IHCs, the classical mechanotransducers, are connected to 95 % of the auditory nerve afferent fibers. In contrast, the outer hair cells are only innervated by 5 % of afferents which are not responsive to sound. One current hypothesis is that the fast mobility of the isolated OHCs, so-called active processes, are responsible for the presence of the otoacoustic emissions. In addition, the cochlea is innervated by two efferent systems: 1) the lateral efferent system coming from the lateral superior olive which modulates the activity of auditory nerve dendrites below the IHCs and 2) the medial efferent system coming from medial nuclei of the superior olivary complex which modulates the OHCs.

When a moderate tonal stimuli (6kHz, 95 dB SPL, 15 min.) was applied, both the compound action potential (CAP) and the distortion product otoacoustic emissions (DPOAEs) recorded in guinea pig showed a maximum hearing loss, not greater than 30 dB, half an octave the exposure frequency. A full recovery was observed 24 hours latter. In addition, no ultrastructural abnormality was found immediately after noise exposure. Since an intracochlear perfusion of a glutamate antagonist (kynurenate) did not reduce the traumatic effect of the intense sound, we concluded that only active processes were affected. In contrast, when strychnine which is known to block the effects of an electrical stimulation of the medial efferents, was perfused in the cochlea, the maximum of shift in CAP threshold was significantly greater (about 12 dB) than that observed in animals exposed to sound during perfusion with artificial perilymph alone. Alltogether, these results suggest that moderate acoustic trauma affects active mechanisms and that an effect of the medial efferents connected to the OHCs may be to act as protectors against auditory fatigue.

In contrast, when the animals were exposed to a more intense sound (6 kHz, 130 dB SPL, 15 min.), the maximum hearing loss was greater than 60 dB, and only a partial recovery was observed 5 days latter. Histological examination immediately after acoustic trauma showed, behind OHCs and IHCs damages, a drastic swelling of the radial afferent dendrites under the IHCs with a loss of the intradendritic content and membrane disruptions. Surprisingly, 5 days latter, while the hair cells damages remained, the IHCs were fully reconnected by the radial afferent dendrites, indicating that the threshold recovery was probably due to the synaptic plasticity of these fibers. Supporting this assumption, glutamate antagonists applied intracochlearly during the same acoustic trauma completely protected the radial dendrites against acoustic trauma-swelling. Preliminary data attesting the involvement of the lateral efferents in the protection of the radial afferent dendrites in such physiopathological conditions will be also presented.

PROTECTIVE FUNCTIONS OF THE MAMMALIAN OLIVOCOCHLEAR PATHWAYS

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The efferent pathways from the superior olivary complex to the cochlea are able to reduce the cochlear desensitization caused by loud sound. The basic protective phenomena of the cochlear efferents were established in experiments in guinea pigs tested with a monaural damaging loud sound at a frequency at about the middle of their hearing range. Protection was elicited by a variety of manipulations including electrical stimulation of the efferent fibers in the brainstem or the presentation of a low-level sound of the same frequency in the ear opposite to the test ear that was presented the damaging loud sound. All the manipulations elicted optimal protection when presented concurrently with the loud sound, but also had long-lasting "tonic" effects such that protection could be obtained even when the manipulations were applied alone some time before the loud sound to the test ear. The protection was confirmed to be due to the olivocochlear pathways (OCBs) by demonstrating, in animals that were paralyzed to eliminate the influence of the middle ear muscles, that protection elicited by each of the various manipulations was blocked by drugs blocking other OCB effects at the cochlea, with a parallel time course of blocking, or by lesioning one OCB component, the crossed OCB (COCB). Across a wide range of exposures of varying intensities and durations, protection was proportional to the desensitization that would otherwise occur. These graded effects saturated at about 15-17 dB reductions in the amount of desensitization at the frequency most affected by the exposure. Experiments in decerbrate animals showed that protection could be obtained solely through lower brainstem connections to the olivocochlear pathways. However higher auditory centers can potentially exercise modulatory influences on this OCB effect, as evidenced by the finding that protection could also be obtained by electrical stimulation in the auditory midbrain. This descending influence is potentially a powerful one since equivalent protection could be obtained at much lower rates of electrical stimulation at the midbrain site than required with direct stimulation of the fibers of passage of the OCB in the brainstem. The finding of protection from a mdibrain site also suggests that the OCB-mediated protection is exercised by only one sub-set of the olivocochlear pathways. More recent experiments in cats have confirmed that protective effects can be obtained by the OCBs in this species, too, thereby confirming the generality of OCB-mediated protection in mammals. The latter studies show that protective OCB effects are elicited more readily by loud sounds that are more damaging than by those that are not, resulting in a frequency-dependence to the protective OCB functions.

BASIC CONCEPTS OF NOISE REGULATIONS IN GERMANY AS COMPARED TO EUROPEAN GUIDELINES

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In the Federal Republic of Germany regulations concerning environmental noise are generally based on the procedure presented in ISO 1996 (except for aircraft noise at civil and military airports).

For assessing the noise exposure a rating level for the daytime (6 - 22 h) or nighttime (22 - 6 h) resp. has to determined and compared to the immission values which are different for the type of residential areas. The immission values should not only protect against deteriorating health effects but should moreover avoid considerable annoyance of the affected population.

The rating level is calculated from the equivalent continous sound pressure level LAeq as the acoustical description of the noise situation and adjustments taking different non-acoustical factors into account which affect the annoyance. The application of these factors listed below may vary from source to source:

K_I: adjustment for impulsive noise
K_T: adjustment for tonal components
K_{Inf}: adjustment for informative noise
K_R: adjustment for exposure during rest period (early morning/evening)
K_{Sit}: adjustment for special local situations
K_{Source}: adjustment for special noise sources (e.g. railway traffic)

In the paper the German regulations for different sources (road traffic, railway traffic, aircrafts, industrial facilities, sporting grounds) will be presented and compared to guidelines in some other European countries.The different immission values, rating times, adjustments and special demands (e.g. meteorology, longterm/shortterm average) having to be fulfilled for compliance with the immission values will be discussed.

REGULATIONS AND STANDARDS AGAINST NOISE FROM ROAD TRAFFIC AND ENTERTAINMENT IN URBAN AREAS OF GREECE

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The problem of noise in the urban areas especially in the South European countries - due to the climatic characteristics - is one of the main causes of annoyance for the people living next to road traffic or entertainment noise sources.

The aim of this paper is to present the work that is currently carried out, mainly from the environmental state services, to forward better legal actions concerning standards and regulations for the following issues :

- noise from road traffic - especially motorcycles - in major urban areas, holiday resorts etc.
- noise from tourist and related (entertainment) activities.
- indoor noise limits.

Certainly the fondamental condition for a successful action against those noise sources is the availability of a dynamic and flexible legal framework which in our country is not yet accomplished.

The first step was to transform and modernize the existing legislation for the Building Codes which included - for the first time in Greece - indoor noise levels for the houses / apartments from the various noise sources.

Regarding traffic noise there is now in use a Ministerial Decision setting the standards of the absolute maximum outdoor noise levels. The limits are 67 and 70 dB (A) for the noise indices Leq (08:00 - 20:00) and L10 (18hr) accordingly. Those limits are valid for all new road schemes, highways etc. On that basis, during the environmental impact analysis of the road scheme there is a prediction of the noise levels and if the previous limits are overpassed then specific anti-noise measures should be taken.

Certain studies that are going on recently showed that people are waiting from the state environmental agencies to proceed faster towards a better acoustical quality in the urban areas.

STANDARDS FOR THE PROTECTION OF COMMUNITY HEALTH

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In preparing environmental noise standards for the protection of community health, every facet of the standard and any resulting legislation must be backed by authenticated scientific research and be capable of withstanding the most severe examination and criticism. Personal feelings have little place except to get the standard off the ground. From then on each step of the way must be accompanied by documentation from an acknowledged and acceptable source.

The formulation of any performance standard and resulting legislation is not easy and with noise legislation there are added difficulties due to the insidious way that noise affects the human body. Indeed there often is sheer disbelief that noise can cause any harm to one's health. It is in providing the necessary backing and prominence that the International Commission for the Biological Effects of Noise (ICBEN) can play a most important role.

There are still many unanswered questions on the biological effects of noise and the need for realistic scientific research is just as important now as ever it was in the past. But there is a difference between the present needs and those of past eras. We have been through the learning process and on the way have accumulated knowledge, much of which, like that learned at school, was interesting at the time but has found little use in practice. For example: The arguments about different frequency weightings and their relative merits are passed, and we have settled down to the realisation that the use of a single frequency weighting is quite adequate for almost all environmental noise measurements where errors due to the effects of other environmental factors far outweigh the minor differences between the result of using the best frequency weighting for that situation and that resulting from using the simple "A" frequency weighting.

With time weightings and time bases, things may be quite different and it is possible that we are on the threshold of a whole new line of research towards the understanding of the adverse effects of excessive noise exposure and how to protect the community from noise that is not of their making.

For the legislator there have been great difficulties in introducing noise controls, and more lie ahead unless some answers are forthcoming to some basic questions. These are discussed in the paper. We need an international consensus on criteria necessary for the protection of personal and public health, and the substantial backing that an organisation such as ICBEN could give. Up until now the Commission has only acted as a forum for the discussion of the latest research into the biological effects of noise. It is suggested that it should now take on the role of an international adviser to governments, collating the results of this research and producing criteria and working performance standards applicable to protecting the health of any nation.

NOISE AND TRAFFIC

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An analysis of the situation in the Spanish cities of environmental noise matters shows that the majority of the population are subject to noise levels which can be considered as excessive.

This sound climate in the cities is caused by the noise coming from the traffic, in cities which were not designed or planned to put up with so much traffic.

Until now, none of the actions taken against the noise of traffic in the cities, have had the expected success, as these actions were taken exclusively on the traffic and not on the real causes of the noise, where the traffic is only an intermediary between the causes (town dispersion, soil uses) and the effects (noise, atmospheric pollution,...).

The techniques normally used to fight against noise: noise control, acoustic screening, porous paving, etc. and even the legislations: decrees, standards, etc., are essential tools but they are also insufficient.

The preparation of noise maps and psychosociological surveys are fundamental elements to find out about the noise problem in the cities and are fundamental for designing the cities in another way.

We will not obtain better results until we design a new model of territorial organization, reducing the people's needs to move about and introducing noise as a town planning parametre.

It is necessary, then, to overcome the purely architectonic planning stage, which only designs the city and the building volumes and which does not prevent congestive uses from being newly established, attracting more people and vehicles, and to go on to a planning whose decrees require a compulsory reduction of the demand for mobility.

If we superimpose the results of the noise maps with the atmospheric pollution isolines and the thermic maps, we can easily see that in many cities, like Zaragoza, the most contaminated areas coincide with the traffic flow maps.

This situation reaffirms, to an even greater extent, the need for the town planning to design the city in a global way, as a way to be able to solve the cities' environmental problems, noise being one of them.

ORIGINAL AND SPECIFIC REGULATION FOR COMPENSATION AGAINST UNHEALTHY NOISE AT EDF - GDF

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The Social Security System in France, and the Statute for the Nationalisation of EDF - GDF were both constituted simultaneously in 1946.

Acceptance at national level of the principle of compensation for exposure to noise at work proved to be impossible. Instead, the option finally adopted was that hearing-loss caused by sound traumatism should be compensated as an occupational illness.

At EDF - GDF it was possible to apply the first option and compensation for unhealthy noise was laid down in one of the articles of the Statute. Effective implementation began in 1956, whereas rules for the admission of deafness, as an occupational illness, were only made in 1963, and then redefined in 1981.

There then followed the various French and international standards which have been used as the basis for implementation of the regulations.

And there again, a substantial contribution to these efforts was made by the Laboratory of Acoustics of the EDF - GDF Directorale of Studies and Research.

- PRESENT SITUATION.

Then came the European Directive in 1986, implemented by a French Ministerial Decree, but which did not modify the upper levels in force in France.

And finally, a "Noise Law" was published by the Ministry of the Environment on 31 December 1992. To assist its implementation a ad hoc working group is now drafting a revision of the NFS 31010 "Characteristics and Measurement of Environmental Noise", in which EDF is participating.

- CONCLUSION

Whatever progress may have been made in this field in respect of Regulations and Standards, the basic principles of compensation for unhealthy noise at EDF - GDF should never have been called into question.

APPLIED NOISE RESEARCH AND ITS EFFECTS ON REGULATIONS AND STANDARDS

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The evaluation of noise induced health hazards should be based on the results of scientific investigations. Physiological responses due to noise impact show in the range of middle-loud and loud sounds a more or less close dose-response curve. Psychological and sociological effects of noise do not provide close dose-response relations. Therefore, other methods and criteria have to be used for the evaluation of noise effects.

Based on experimental data and practical experience in most countries, levels of 85 dB(A) ± 5 dB(A) are regarded to be harmful for the hearing organ. Legislative provisions (national) or recommendations (international) are adapted as guidelines or limits for noise exposure at workplaces. For many other fields of noise exposure limits or guidelines have been established which often differ widely between several countries. The question arises if it would be desirable, useful or even compulsory to establish common guidelines or limits on an international level. Combined which these situation the question arises if scientific research is sufficient for such an establishment of regulations.

The newly founded team 9 of ICBEN "Regulations and Standards", which took place at the end of the Stockholm Conference in 1988, has had its constitution at the Nice Conference 1993 and will deal within the near future with these questions. It has to be decided if it would be helpful for the noise control to establish risk tables and commonly accepted guidelines for the various fields of noise loads (community noise, occupational noise etc.) and for the various field of noise effects.

WHO, European Community (EC) and other supranational institutions have published various overviews and papers concerning regulations and standards. The work of Team 9 of ICBEN has to concentrate on the evaluation of scientific results (experimental and epidemiological) and on equalization and (necessary) differentiation of standards which are contained in the papers mentioned above.

The papers and communications of the present conference are the beginning of Team 9 work. It is expected that national and international authorities will promote and assist members of Team 9 in their work.

PSYCHOLOGICAL FACTORS IN COMMUNITY REACTION TO NOISE

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The reaction to noise of humans living in residential communities near noise sources has been under investigation for over thirty years. The curve relating noise exposure to extent of reaction (typically restricted to annoyance), although not uniformly agreed upon, appears reasonable within somewhat wide error bands. However, the extent to which individual reaction to noise can be predicted from noise exposure is notoriously low. The variance in reaction is not remotely fully accounted for, even with consideration of the contribution of modifying or moderating variables and the error in measurement of the reaction, measurement of exposure and measurement of modifying variables. This is an important finding in that it may indicate that influential variables remain as yet undiscovered. These hypothetical undiscovered variables may be of considerable theoretical and/or practical consequence.

In this paper consideration of psychological factors has been restricted to reaction, mental health consequences of noise, and the factors which may contribute to each of these. Other than hearing loss (and possibly blood pressure), reaction and mental health effects appear to be the best supported effects of noise exposure within the literature. While the effects of noise may contribute to a variety of mental health problems, the most important is depression. Depression is of special significance for three reasons. First, it is more common than most major psychiatric disorders and minor depression is still more common. Second, a major model of depression (learned helplessness theory and related research) suggests that exposure to unpredictable events over which we have no control is an important precipitating factor in depression. Third, depression and helplessness appear to be related to other important health effects such as distress syndrome and impaired immune functioning. The variables implicated by this model of depression are therefore included as variables in need of further research in relation to reaction to noise.

The present paper presents an attempt to structure the research field around identification and examination of the factors contributing to, and the measurement of, community reaction to noise. The research field is divided into five major areas: measurements of exposure; extrinsic moderating factors; intrinsic moderating factors; confounding factors; and measurements of reaction and mental health. The contribution of the present overview is to identify a number of important possible variables in measurement of reaction and modulators which have been largely overlooked, and to identify the need to consider complex interactions such that certain exposure or modulating factors may contribute differentially to the different aspects of reaction.

Each set of variables is considered in turn although it should be noted that the classification of variables sometimes depends on underlying assumptions and is therefore somewhat arbitrary.

Measurements of exposure. Exposure has been comprehensively measured in many studies, which have often considered dozens of noise variables in terms of their ability to predict reaction. Noise frequency, energy, peak, number of events, number of events exceeding a particular threshold, and many other indices combined with various weightings for time of day have been researched. However, it is well recognised that exposure involves more than simply the noise exposure of the dwelling. The actual noise exposure received by an individual is also contributed to by the amount of time and times of day they spend at home, the noise insulation of the dwelling, and the amount of time spent indoors versus outdoors. Nonetheless, it is not clear that reaction to noise is determined by actual individual exposure rather than dwelling exposure.

Learned helplessness theory suggests that the impact created by the noise may also be influenced by other as yet unexplored factors of the noise such as its predictability. This is largely determined by the rise time or the consistency of intervals between the noise events. Indeed, unpredictability may be a major cause of the reliably greater reaction elicited by impulsive noise in comparison with more steady state or slow rise time noise sources.

Extrinsic moderating factors. Some extrinsic moderating factors have been considered in relation to community reaction to noise. For example, exposure to other noises in the home and controllability of the noise. Controllability may be determined largely by lifestyle and dwelling design factors- ie. can the occupant move to a less exposed room or close the windows. Learned helplessness suggests that noise controllability is an important variable.

Intrinsic moderating factors. These include hearing acuity, various demographic variables (age, sex, socio-economic status, home ownership), and dispositional and attitudinal variables (satisfaction with the neighbourhood, attitude towards the noise source and related personnel, noise sensitivity, susceptibility to annoyance or other reactions) which have generally received considerable attention. Again, for learned helplessness subjective perceived controllability and predictability of the noise are potentially relevant. Personality factors related to the pessimism/optimism dimension and individual differences in the meaning attached to words like moderately, considerably, very and highly may also aid in accounting for more of the variance in reaction.

Confounding Variables. Certain variables may contribute to the outcome of noise (eg. mental health) without modifying reaction to noise. Such variables deserve consideration in order to increase our understanding of the outcomes being researched and to reduce the unexplained variance of the outcome measures. Confounders may include genetic or familial factors of depression and mental illness and other susceptibility factors, noise exposure away from the home such as at work, predictability and controllability in other areas of life, and other stressors.

Measures of reaction and depression. Measurement of reaction has varied from a single question on annoyance to evaluation of a variety of aspects of reaction (fear, frustration, dissatisfaction, anger, extent of unspecified effect, general disturbance, activity disturbance, sleep loss, other losses). The restriction of reaction to annoyance when other quite different reactions may be elicited in individuals is an unfortunate choice. Research should broaden the measurement of reaction to include possibilities other than simple annoyance. Learned helplessness theory and supporting evidence suggests that depression should be examined.

This overview supports five conclusions:

1. Despite our efforts, community reaction to noise is not yet well understood or statistically accounted for.
2. Reaction itself is often inadequately measured by being restricted to annoyance only. People may react to noise in many different ways. An unpresumptuous question on the extent of unspecified effect is especially desirable.
3. The weight of evidence and the relevance of exposure to uncontrollable, unpredictable events (such as noise) suggest that consideration of the variables relevant to helplessness is warranted.
4. The direction of causation for some major variables of reaction (notably attitude) remain to be unambiguously established. This may be done by manipulation of the relevant variable: the experimental rather than the observational method.
5. The possibility exists that exposure or moderating variables are differentially influential on various components of reaction. For example, the unpredictability of noise may influence nervousness or distress whereas event duration may have more impact on interference with watching television or telephone conversation. Such features may also influence fear or disturbance differentially from annoyance. The assumed homogeneity of the concept of community reaction must be questioned. -

TECHNICAL ASPECTS OF NOISE IMMISSION REDUCTION FROM LAND TRANSPORT

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As road traffic is the most important noise source in most cities, a great deal of research has been devoted to the vehicles and to the traffic organisation since the sixties.

THE ROAD VEHICLES AND THE TRAINS

Future vehicle noise legislation - particularly in Europe and Japan - demands the development of low noise power train and silent tires. Shieldings and enclosures present disadvantages in terms of cost and accessibility for maintenance; therefore, to meet future more stringent noise requirements, new unconventional engine and exhaust concepts will have to incorporate all feasible noise reduction measures already in the design stage. Most vehicles from the smallest motorcycle to the most powerful truck can be quietened to reach the targets of 76-78 dB(A) under the standard tests.

Considering the cost and the capabilities of electric vehicles, regulatory measures will be needed like in California in order to help their introduction in sensitive urban areas. Conventional buses emit 10 dB(A) more than most cars, very encouraging experiments have been done with electric buses, trolley buses, Diesel bus with encapsulated engines.

Rolling noise is increasingly becoming the dominant form of noise, it can be expressed by Lmax = Cs log V + a constant, where Cs has a value lying between 25 and 40. For trains the rolling noise depends on Roughness spectrum of the rail or of the wheel. For perfect conditions of rails and wheels and for high speeds, the noise can be emitted at resonant vibration frequencies of the wheels; resilient wheels are developed.

Fitting of skirts over the wheels is not encouraging because of the inability to shield both wheel and rail. Use of disc brakes in place of tread brakes allow a significant rolling noise reduction on the TGV Atlantique non powered cars. The same change will bring a significant reduction in power car noise. Use of articulated vehicles, and hence fewer wheels, has proved beneficial, with the TGV. Another effective means of rolling noise control is the installation of barriers or screens alongside the track.

The aerodynamic noise will be dominant for speeds greater than 300-350 km/h; pantographs together with the front faces of the train are the main sources of aerodynamic noise. The aerodynamic noise is a reason why the MAGLEV system appear not to be quieter than the conventional high speed trains.

THE INFRASTRUCTURE AND THE ROAD TRAFFIC

By using a porous surface it is usually possible to obtain a noise reduction of approximately 5 dB(A) on high-speed roads. Such a reduction could be obtained also on low-speed roads/streets but then road maintenance are required : in most cases, surfaces get clogged with time and noise reduction is destroyed in just a few years.

For low and medium density areas, noise screens such as banks, walls, wood, glass or metal panels are widely used. Most American and European barriers are deflective and rather cheap. Absorbent screens are necessary in cases with some risks of multiple reflections of noise waves. In very densely populated area with tall buildings part or complete covering lessens the noise level by 20 dB(A). The complete cover allows organisation of urban activities on multiple levels; underground roads and railways will be the only acceptable solution in most of the cases.

The local authorities may very much improve the environment by detailed actions on access ways and by favouring silent vehicles such as electric vehicles. Traffic signals, parking facilities and prices, road pricing, partial closing of some streets etc. can reduce the speeds and exclude unnecessary and/or noisy traffic. Improvements to urban area need carefully studied steps : 1- Divert a great par of motor vehicles to outer highways. 2 - Reorganise the public transport. 3 - Build car parks outside the area. 4 - Restrict traffic in most streets for authorised vehicles, bus, etc.

Interesting concepts of car free areas or traffic restraints have been applied in North Europe and Italy. After the speed limit on several city roads was changed from 50 km/h to 30 km/h, the noise levels were reduced by 2-4 dB(A) also because of changes to the driving style adopted.

Severe restrictions in terms of place or time and place may be placed on the movements of heavy goods vehicles while "low-noise" vehicles may be exempted from these restrictions.

BUILDINGS AND TOWN PLANNING

The insulation of high rise building bordering suburban highway is commonly practised in France. The building industry produces efficient panel and windows for noise and thermal insulation. The energy crisis contributes in some way to the acoustical improvements of the buildings but one must distinguish between the acoustic and thermal properties of the building parts.

The open building lay-out which was favoured by most European architects after 1945 increases the noise immission levels; it seems necessary to built again in "closed shapes" : building enclosing quiet area ensure silent facades and grounds. In high occupation density areas, the construction of buildings close to the infrastructure makes it possible to better use the tertiary sector, protect the residential zones. Non motorised transport as cycling is of considerable interest from the standpoint of the environment.

The linear town of the Athens charter in 1929 intended to create sharp division between quiet areas (residential, recreational) and noisy areas (traffic, business, factories). But the spread of road vehicles and the change in the type of industry have reduced the interest in the separate zoning concepts.

CONCLUSION

The main nuisance in our towns is now the traffic noise and the traffic volumes are expected to increase heavily in the coming years. If we except some rare new towns and car free areas, it will be a very difficult task to get a satisfactorily quietness in all urban areas. The road vehicles emissions will be reduced by 5 to 10 dB(A) in 10 years, some electric vehicles will be used for specific purposes, but with the increases in traffic these efforts will not be sufficient to reach good results in all our urban areas in year 2000 - 2010. The energy crisis can be considered as a useful help for noise control : the drivers can gain considerably both in terms of fuel saving and in the noise emission.

Any noise abatement strategy needs a comprehensive approach which must include not only Evaluation of acoustical benefits but also Assessment of other factors related to the environment of urban areas. Town planning must be used as an administrative tool to reduce noise disturbance and to adapt the traffic to the town.

ASPECTS TECHNIQUES DE LA REDUCTION DU BRUIT DES TRANSPORTS TERRESTRES

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Le trafic routier étant la plus importante source de bruit dans la plupart des villes, de nombreuses recherches ont été consacrées aux véhicules et à l'organisation du trafic depuis les années 60.

LES VEHICULES ROUTIERS ET LES TRAINS

Les prochaines législations sur le bruit des véhicules -en particulier en Europe et au Japon- prévoient le développement de groupe motopropulseurs à faible émission de bruit et de pneus silencieux. Les écrans et encapsulages présentent des inconvénients en terme de coûts et de facilité d'entretien; par conséquent, pour répondre dans le futur aux réglementations sur le bruit toujours plus rigoureuses, les moteurs non-conventionnels et les concepts d'échappements nouveaux devront incorporer toutes les mesures de réduction du bruit envisageables dès le stade du dessin. La plupart des véhicules, du plus petit des motocycles au plus puissant des camions, peuvent être insonorisés de façon à atteindre 76-78 dB(A) dans les conditions de la norme.

Considérant le prix et les capacités des véhicules électriques, des mesures réglementaires seront nécessaires, comme en Californie pour favoriser leur introduction dans des zones urbaines sensibles. Les autobus conventionnels émettant 10 dB(A) de plus que la plupart des voitures, des expériences très encourageantes ont été réalisées avec des autobus électriques, des trolleybus, des autobus Diesel aux moteurs encapsulés.

Le bruit de roulement devient de plus en plus la forme dominante de bruit, il peut être exprimé par : $L_{max} = C_s \log V +$ une constante, où C_s a une valeur comprise entre 25 et 40. Pour les **trains**, le bruit de roulement dépend du spectre des rugosités du rail ou des roues. Pour des conditions parfaites des rails et des roues et pour des vitesses plus grandes, le bruit peut être émis par les résonances des roues; des roues amorties sont développées.

L'ajustement de jupes sur les roues n'est pas encourageant en raison de l'impossibilité de supprimer le rayonnement du rail. L'utilisation de freins à disques au lieu de freins à tambour permet une réduction du bruit sur les voitures non motorisées du T.G.V. Atlantique. Le même changement apportera des réductions de bruit sur les voitures motorisées. L'utilisation de véhicules articulés s'est révélée avantageuse pour le T.G.V. car elle réduit le nombre de roues. Un autre moyen de contrôle du bruit est l'installation de barrières ou d'écrans le long de la voie.

Le bruit aérodynamique sera dominant pour des vitesses supérieures à 300-350 km/h.. Les pantographes et les faces frontales des trains sont les sources principales du bruit lié à l'aérodynamisme. Le bruit aérodynamique est la raison pour laquelle le système MAGLEV semble ne pas être plus silencieux que les trains conventionnels.

LES INFRASTRUCTURES ET LE TRAFIC ROUTIER

Avec les revêtements routiers poreux, il est normalement possible d'obtenir une réduction du bruit d'environ 5 dB(A) sur les voies à grande vitesse. Une réduction de cet ordre peut être également obtenue sur les routes/rues à vitesse réduite, mais ceci exige une maintenance de la route: dans la plupart des cas, les surfaces s'obstruent avec le temps et la réduction du bruit est détruite en très peu d'années.
Pour des secteurs de faible et moyenne densité d'habitation, des écrans contre le bruit tels que des talus, des murs, des panneaux en bois, verre ou métal sont largement utilisés. La plupart des barrières américaines et européennes sont réfléchissantes et plutôt bon marché. Des écrans absorbants sont nécessaires dans les cas de

risque de réflexions multiples des ondes de bruit. Sur des aires à population très dense, ayant de hauts immeubles, une couverture partielle ou complète peut atténuer le niveau du bruit de 20 dB(A). La couverture complète permet une organisation des activités urbaines à plusieurs niveaux : des routes et des voies ferrées souterraines sont dans la plupart des cas la seule solution acceptable.

Les autorités locales pourront améliorer l'environnement par des actions détaillées sur les voies d'accès et en favorisant les véhicules silencieux tels que les véhicules électriques. Les signaux routiers, les disponibilités de stationnement et les prix, les péages urbains, la fermeture partielle de certaines voies, etc... peuvent réduire la vitesse et écarter un trafic inutile et/ou bruyant. Les améliorations des aires urbaines nécessitent des étapes soigneusement étudiées: 1- détourner une grande partie des véhicules vers les autoroutes extérieures. 2- réorganiser le transport public. 3- construire des parkings à l'extérieur de l'aire. 4- restreindre le trafic dans la plupart des rues aux véhicules autorisés, bus, etc...

Des concepts intéressants de zones sans voitures ou à trafic restreint ont été appliqués en Europe du Nord et en Italie. Suite aux limitations de vitesse passant de 50 km/h à 30 km/h sur certaines voies urbaines, le niveau de bruit a été réduit de 2 à 4 dB(A), grâce également aux changements du style de conduite adoptée.

Des restrictions sévères dans le temps et l'espace pourraient être prévues sur les mouvements des véhicules lourds, alors que les véhicules "peu bruyants" pourront en être exemptés.

IMMEUBLES ET ORGANISATION DE LA VILLE

L'insonorisation des grands immeubles bordant les autoroutes des banlieues est souvent pratiquée en France. L'industrie du bâtiment produit des panneaux et des fenêtres efficaces pour l'isolation acoustique et thermique. La crise de l'énergie contribue d'une certaine façon aux améliorations acoustiques des immeubles, mais nous devons distinguer les propriétés acoustiques des propriétés thermiques des éléments de construction.

Les plans de masse ouverts des immeubles favorisés par la plupart des architectes européens après 1945, augmentent les expositions au bruit; il semblerait nécessaire de revenir à des "formes closes" : des immeubles renfermant une zone calme assurent des façades et des aires extérieures silencieuses. Dans des aires de haute densité d'occupation, la construction d'immeubles près des infrastructures rend possible une meilleure utilisation du secteur tertiaire, protégeant les zones résidentielles. Des transports non motorisés, tels que les cycles, sont d'intérêt considérable du point de vue de l'environnement.

La ville linéaire selon la charte d'Athènes en 1929 essaya de créer une distinction précise entre les secteurs calmes (résidences, zones de loisirs) et les secteurs bruyants (trafic, commerces, industries). Mais la multiplication des automobiles ainsi que le changement du type d'industrie ont réduit l'intérêt porté au concept de zoning.

CONCLUSION

La nuisance principale dans nos ville est aujourd'hui le bruit du trafic, et il semble que la circulation ne fera qu'augmenter lourdement dans les années à venir. Exceptées quelques rares villes nouvelles et des zones sans voitures, la tâche pour arriver à un calme satisfaisant dans toutes les aires urbaines sera très difficile. Les émissions des véhicules routiers seront réduites de 5 à 10 dB(A) en 10 ans, certains véhicules électriques seront utilisés dans des buts spécifiques, mais avec l'augmentation du trafic, ces efforts ne suffiront pas à atteindre de bons résultats pour nos villes dans les années 2000-2010. La crise de l'énergie peut être considérée comme une aide utile pour le contrôle du bruit : par une conduite appropriée les conducteurs peuvent gagner autant en terme d'économie d'essence que d'émission de bruit.

Toute stratégie d'abaissement du bruit nécessite une approche intégrée qui devra inclure non seulement une Évaluation des avantages acoustiques mais aussi une Estimation des autres facteurs reliés à l'environnement des aires urbaines. La planification urbaine doit être utilisée comme un outil pour réduire les troubles liés au bruit, et pour adapter le trafic à la ville.

AUTHORS INDEX - INDEX DES AUTEURS

Volumes 1 and 2 - Volumes 1 et 2

for the global index see volume 3 - pour l'index global voir volume 3

Session	Author - Auteur	Vol - Page
2	Abel SM	1 - 18
9	Aboukhalil E	2 - 625
6	Aecherli W	2 - 321
6	Aguerri Sanchez MP	2 - 323
6	Ahrlin U	2 - 605
1	Ahroon WA	2 - 57
1	Ahroon WA	2 - 1
1	Al Masri M	2 - 5
6	Al-Felimban A	2 - 379
6	Al-Humud JM	2 - 379
6	Albanese G	2 - 221
6	Albanese G	2 - 327
1	Alberti PW	1 - 41
8	Allen KM	2 - 269
1	Allen NK	2 - 101
5	Altena K	2 - 575
9	Alvares JR	2 - 643
9	Alvares PA	2 - 441
1	Andersen T	2 - 39
1	Andersen T	2 - 9
7	Anderson BA	2 - 247
5	Aoki S	2 - 579
6	Arras C	2 - 359
6	Arribas GE	2 - 331
1	Attanasio G	1 - 64
6	Aubree D	2 - 335
1	Avan P	2 - 13
1	Avan P	2 - 79
1	Axelsson A	2 - 119
3	Babisch W	1 - 23
3	Babisch W	1 - 24
6	Barbaro S	2 - 221
6	Barbaro S	2 - 327
7	Barber DS	2 - 247
6	Bartels KH	2 - 339
6	Baughan CJ	2 - 585
5	Beersma DGM	2 - 575
6	Belderrain ML	2 - 401
1	Belderrain ML	2 - 99
3	Belojevic G	2 - 489
4	Belojevic G	2 - 547
1	Bennett J	2 - 17
2	Bennett JDC	2 - 161
4	Benton S	2 - 539
6	Berglung B	2 - 343
6	Berry BF	2 - 597
9	Berry BF	1 - 13
6	Bertoni D	2 - 593
1	Bertrand RA	2 - 21
6	Bisio G	2 - 347
6	Björkman M	2 - 225
6	Björkman M	2 - 351
3	Bly SHP	2 - 509
1	Bohl CD	2 - 38
1	Bonfils P	2 - 13
opening	Bonnefoy X	1 - 6
2	Borchgrevink HM	2 - 193
1	Borchgrevink HM	2 - 25
1	Borchgrevink HM	2 - 53
7	Borchgrevink HM	2 - 255
1	Borg E	1 - 62
7	Bosova L	2 - 265
7	Bowles AE	1 - 27
7	Bowles AE	2 - 260
8	Breysse P	2 - 291
8	Brockman P	2 - 311
8	Bröde P	2 - 277
3	Bröde P	2 - 457
6	Buchta E	1 - 59
6	Bugge JJ	2 - 589
4	Bullinger M	1 - 37
1	Canlon B	1 - 63
6	Carles JL	2 - 205
2	Carme C	2 - 149
1	Carme C	2 - 29
8	Carrick L	2 - 287
5	Carter NL	1 - 51
3	Carter NL	2 - 469
1	Causse JB	2 - 33
9	Celma Celma J	1 - 70
6	Celma Celma J	2 - 323
6	Champelovier P	2 - 389
6	Champelovier P	2 - 425
9	Chan RH	2 - 647
6	Chaussonnery R	2 - 355
1	Chen J	2 - 37
1	Chen M	2 - 37
1	Clark WW	2 - 38
8	Clausen G	2 - 287
1	Cohen A	2 - 115
6	Cosa M	2 - 221
6	Cosa M	2 - 327
2	Costabal H	2 - 181
6	Côté P	2 - 397
1	Courtois J	2 - 39
1	Courtois J	2 - 9
5	Crawford G	1 - 51
1	Custard G	2 - 43
2	Dajani H	2 - 165
7	Damon E	2 - 255
1	Dancer A	1 - 44
6	Dankittikul W	2 - 197
6	Dankittikul W	2 - 217
1	Davis RI	2 - 57
1	Davis AC	1 - 42
1	Davis RI	2 - 1
3	Day RD	2 - 461

6	De Jong HJ	2 - 609	7	Gladwin DN	2 - 243
6	De Jong RG	1 - 57	3	Goddard M	2 - 509
7	De Youg DW	1 - 28	7	Golightly R	1 - 27
7	De Young DW	2 - 251	9	Goncalves S	2 - 639
2	Deleurence P	2 - 173	9	Gottlob D	1 - 67
2	Delgado C	2 - 153	6	Granoien ILN	2 - 589
7	Denaster DP	2 - 260	8	Griefahn B	2 - 277
4	Dewasmes G	2 - 519	5	Griefahn B	1 - 47
5	Dewasnes G	1 - 54	3	Griefahn B	2 - 457
6	Di matteo U	2 - 327	6	Griffiths ID	2 - 583
5	Diamond I	2 - 573	6	Grippaldi V	2 - 221
5	Diamond ID	1 - 48	6	Grippaldi V	2 - 327
9	Dickinson P	1 - 69	8	Groll-Knapp E	1 - 34
6	Droin L	2 - 359	5	Gruber J	1 - 53
8	Du D	2 - 317	8	Gueiros Teixeira S	2 - 307
9	Duclos JC	2 - 625	1	Guy M	2 - 95
5	Eberhart J	2 - 559	8	Haider M	1 - 34
1	Eden D	2 - 47	1	Hallmo P	2 - 53
2	Edworthy J	1 - 20	1	Hamernik RP	2 - 1
5	Egger P	2 - 573	1	Hamernik RP	2 - 57
9	Eghtesadi K	2 - 447	7	Harrington FH	2 - 239
5	Ehrhart J	1 - 54	7	Hayes CL	1 - 28
4	Ehrhart J	2 - 519	4	Hellbrück J	1 - 39
3	Elwood P	1 - 24	4	Hellbrück J	2 - 557
3	Elwood PC	1 - 23	1	Hellström PA	2 - 61
6	Erdem Aknesil A	2 - 619	1	Henderson D	1 - 64
7	Etchberger RC	2 - 251	1	Henderson D	2 - 65
4	Evans GW	1 - 37	6	Hermand D	2 - 371
8	Evans GW	2 - 269	2	Hétu R	2 - 169
4	Evans GW	2 - 515	3	Hiramatsu K	2 - 473
			5	Hofman W	2 - 559
4	Fakkar S	2 - 523	5	Holmes D	2 - 573
8	Fanger PO	2 - 287	5	Horne JA	1 - 50
7	Faustov A	2 - 265	5	Horne JA	2 - 567
8	Fechter L	2 - 291	8	Hörtnagl H	1 - 34
1	Fernandes JC	2 - 51	2	Houtgast T	1 - 16
6	Fields JM	1 - 58	6	Huddart L	2 - 585
3	Findlay RC	2 - 461	5	Hume KI	1 - 49
6	Finegold LS	2 - 229	5	Hume KI	2 - 563
6	Finegold LS	2 - 363	5	Hume KI	2 - 569
6	Flottorp G	2 - 423	5	Hunyor SN	1 - 51
9	Fogel AL	2 - 445	4	Hygge S	1 - 37
7	Fraiman B	2 - 265	4	Hygge S	2 - 531
3	Fraiman BJ	2 - 501			
3	Fraiman EB	2 - 501	3	Imai H	2 - 505
6	Franchini A	2 - 593	2	Irvine DRF	2 - 437
7	Francine JK	1 - 27	3	Ishii EK	2 - 461
9	Fridman VE	2 - 445	1	Ishii EK	2 - 69
1	Fritze W	2 - 75	6	Ishiyama T	2 - 375
			3	Ising H	1 - 23
1	Gagliano A	2 - 105	3	Ising H	1 - 26
3	Gallacher J	1 - 24	3	Ito A	2 - 473
6	Gallardo C	2 - 331	6	Izumi K	2 - 197
1	Gamba R	2 - 95	6	Izumi K	2 - 217
6	Garcia A	2 - 367			
6	Garcia AM	2 - 367	9	Jansen G	1 - 72
6	Giaconia C	2 - 221	8	Jansen G	2 - 279
6	Giaconia C	2 - 327	3	Jansen G	2 - 485
2	Gilloire A	2 - 173	3	Jansen G	2 - 497
2	Giua PE	2 - 157	1	Jedlinska U	2 - 127
6	Gjestland T	2 - 589	3	Jenkins A	2 - 469

7	Jenssen A	2 - 255
key note	Job RFS	1 - 73
3	Job RFS	2 - 469
1	Johnson DL	1 - 43
5	Jones C	1 - 55
4	Jones DM	1 - 38
7	Joyce MR	2 - 247
3	Kabuto M	2 - 505
3	Kageyama T	2 - 505
6	Kalivoda MT	2 - 233
6	Karabiber Z	2 - 619
5	Kawada T	2 - 579
5	Kelly D	1 - 51
2	Kersebaum M	2 - 161
1	Kersebaum M	2 - 17
4	Khardi S	2 - 523
4	Kilcher H	1 - 39
4	Kilcher H	2 - 557
8	Kim SW	2 - 287
1	Kochanek K	2 - 135
3	Kocijancic R	2 - 489
3	Kofler W	2 - 465
1	Köhler W	2 - 75
9	Koppert AJ	2 - 651
6	Koushki PA	2 - 379
6	Koyasu M	2 - 385
6	Krajcovic M	2 - 381
7	Krausman PR	1 - 28
7	Krausman PR	2 - 251
6	Krueger H	2 - 601
7	Kugler AB	2 - 247
7	Kugler BA	1 - 29
7	Kull R	1 - 27
7	Kull RCJ	1 - 31
3	Kuller LH	2 - 461
8	Kullman G	1 - 35
5	Kumar A	2 - 559
2	Kunov HL	2 - 165
6	Kurosawa K	2 - 197
6	Kurosawa K	2 - 217
6	Kurra S	2 - 613
6	Kuwano S	2 - 385
9	Kwan A	2 - 647
6	Lambert J	1 - 61
6	Lambert J	2 - 389
Key note	Lamure CA	1 - 75
3	Lanzendörfer A	2 - 485
2	Laroche C	2 - 169
9	Laroche C	2 - 655
2	Larocque R	2 - 169
1	Larsen BV	2 - 39
1	Larsen H	2 - 39
2	Lauri ER	2 - 177
2	Lazarus H	1 - 17
2	Le Breton B	2 - 173
6	Lecointre G	2 - 371
1	Lei SF	2 - 57
5	Leiss R	1 - 53
6	Lemieux P	2 - 397
6	Leobon A	2 - 393
1	Leplay A	2 - 95
6	Lercher P	2 - 201
3	Lercher P	2 - 465
9	Leroux T	2 - 655
6	Liasjo KH	2 - 589
4	Libert JP	2 - 519
8	Liu H	2 - 317
7	Liu S	2 - 261
9	Looten A	2 - 659
6	Lopez Barrio I	2 - 205
1	Loth D	2 - 13
1	Loth D	2 - 79
1	Luca A	2 - 105
6	Lundquist B	2 - 605
1	Lutman ME	1 - 42
9	Luzy A	2 - 625
4	Macken B	1 - 38
6	Magnoni M	2 - 593
1	Mair IWS	2 - 53
8	Manninen O	1 - 32
4	Maramotti I	2 - 543
1	Martin A	2 - 5
5	Maschke C	1 - 53
2	Matamala P	2 - 181
8	Matanoski G	2 - 291
8	Maurin M	2 - 273
7	McClenaghan L	1 - 27
7	McKechnie AM	2 - 243
1	McKinley RL	2 - 83
3	McLean J	2 - 509
8	Mehnert P	2 - 277
6	Meloni T	2 - 601
1	Menguy C	2 - 13
1	Menguy C	2 - 79
2	Messino CD	2 - 157
1	Meyer-Bisch C	2 - 87
3	Meyer-falcke A	2 - 485
6	Miedema HME	1 - 60
6	Migneron JG	2 - 397
1	Mills JH	2 - 91
3	Minami M	2 - 505
6	Moch A	2 - 371
4	Moch A	2 - 543
6	Molina M	2 - 331
1	Mondot JM	2 - 95
7	Mönig T	2 - 259
9	Morelli L	2 - 635
3	Morrell S	2 - 469
1	Mozo BT	1 - 43
7	Murphy SM	1 - 29
7	Murphy SM	2 - 247
opening	Muzet A	1 - 3
5	Muzet A	1 - 54
4	Muzet A	2 - 519
9	Nabuco M	2 - 639
5	Naganuma S	2 - 579
3	Nakasone T	2 - 473
key note	Namba S	1 - 8
6	Namba S	2 - 385
1	Nedwell J	2 - 5

6	Nepomuceno JA	2 - 401
1	Nepomuceno JA	2 - 99
5	Nicolas A	1 - 54
4	Nicolas A	2 - 519
8	Nikolic	2 - 283
3	Nitta H	2 - 505
1	Nixon CW	2 - 101
1	Nixon CW	2 - 83
9	Normand JC	2 - 625
8	Notbohm G	2 - 279
3	Notbohm G	2 - 497
8	Nunes Cossenza CA	2 - 307
9	O'Rourke ST	2 - 629
5	Ogawa M	2 - 579
5	Öhrström E	1 - 52
5	Öhrström E	1 - 56
6	Öhrström E	2 - 209
6	Öhrström E	2 - 403
4	Öhrström E	2 - 547
4	Olivier D	2 - 523
5	Ollerhead JB	1 - 48
5	Ollerhead JB	1 - 55
1	Olofsson A	2 - 131
2	Pachiaudi G	2 - 173
7	Palka D	2 - 260
5	Pankhurst FL	1 - 50
5	Pankhurst FL	2 - 567
2	Pascal D	2 - 173
8	Pascher G	1 - 35
1	Passchier-Vermeer W	1 - 40
1	Passchier-Vermeer W	2 - 141
1	Patania F	2 - 105
1	Patterson JH	1 - 43
1	Patterson JH	2 - 1
2	Pekkarinen E	2 - 177
2	Pekkarinen E	2 - 189
8	Pena B	2 - 291
3	Peploe P	2 - 469
opening	Perera P	1 - 4
2	Perera P	2 - 153
6	Persson K	2 - 407
4	Petit C	2 - 527
6	Pichon JL	2 - 621
9	Pietry Verdy MF	1 - 71
9	Pignat JC	2 - 625
1	Pimenta A	2 - 123
9	Pimentel-Souza F	2 - 441
8	Pjerotic L	2 - 283
9	Porter ND	1 - 13
6	Porter ND	2 - 597
8	Poulsen T	2 - 287
3	Poustka F	2 - 477
1	Precerutti G	2 - 109
6	Preis A	2 - 343
1	Price GR	2 - 113
8	Prince M	2 - 291
9	Prince MM	2 - 633
9	Psichas K	1 - 68
6	Psichas K	2 - 615
[illegible]	Puel JL	1 - 65
1	Pujol R	1 - 45
3	Rack R	2 - 485
1	Rajan R	1 - 66
2	Rajan R	2 - 437
3	Rebentisch E	1 - 26
6	Renew WD	2 - 213
8	Rentzsch M	1 - 35
5	Reyner LA	1 - 50
5	Reyner LA	2 - 567
1	Ribeiro J	2 - 115
1	Ribeiro V	2 - 115
1	Ribeiro V	2 - 123
7	Richmond DR	2 - 255
8	Rindel JH	2 - 287
4	Robinson G	2 - 539
9	Rohrmann B	2 - 663
1	Rosenhall U	2 - 119
2	Roure A	2 - 149
1	Roure A	2 - 29
1	Rydzynski K	2 - 127
6	Rylander R	2 - 225
6	Rylander R	2 - 351
6	Rylander R	2 - 407
4	Rylander R	2 - 547
6	Rylander R	2 - 605
1	Sa-Leal A	2 - 123
8	Saito K	1 - 33
4	Salame P	2 - 519
4	Santalla Z	2 - 549
4	Santalla Z	2 - 553
2	Santiago JS	2 - 153
4	Santisteban C	2 - 549
4	Santisteban C	2 - 553
6	Sato T	2 - 411
5	Sato T	2 - 579
6	Schiapparelli P	2 - 347
3	Schmeck K	2 - 477
9	Schmidt DE	2 - 643
8	Schuemer-Kohrs A	2 - 299
8	Schust M	2 - 303
3	Schust M	2 - 513
3	Schwarze S	1 - 22
3	Schwarze S	2 - 497
2	Seballos S	2 - 181
3	Selvin S	1 - 25
6	Serefhanoglu M	2 - 619
2	Seshagiri B	2 - 165
6	Shield B	2 - 415
3	Shine P	2 - 481
2	Sihvo M	2 - 177
1	Silva-Carvalho A	2 - 123
8	Sinz A	2 - 299
6	Skånberg AB	2 - 403
8	Slama JG	2 - 307
1	Sliwinska-Kowalska M	2 - 127
1	Sliwinska-Kowalska M	2 - 135
4	Smith AP	1 - 36
8	Smith AP	2 - 311
4	Smith AP	2 - 535
2	Smoorenburg GF	1 - 19

7	Smultea M	2 - 260
6	Sneddon MD	2 - 363
9	Sobolev LY	2 - 445
6	Sörensen S	2 - 225
1	Sousa-Uva A	2 - 123
6	Soyer M	2 - 621
3	Spear RC	1 - 25
3	Spear RC	2 - 493
1	Spencer HS	1 - 42
6	Springers M	2 - 235
6	Staats HJ	2 - 609
3	Stankovic T	2 - 489
3	Stansfeld SA	1 - 24
3	Stansfeld SA	2 - 481
9	Stayner LT	2 - 633
1	Steele DG	2 - 145
9	Steele DG	2 - 455
7	Stephan E	1 - 30
7	Stephan E	2 - 259
1	Subramaniam M	1 - 64
1	Subramaniam M	2 - 65
1	Sulkowski WJ	2 - 127
1	Sulkowski WJ	2 - 135
8	Suvorov GA	2 - 315
5	Suzuki S	2 - 579
1	Svedberg A	2 - 119
1	Svensson EB	2 - 131
9	Szwarc A	2 - 643
4	Tafalla RJ	2 - 515
8	Taffala R	2 - 269
2	Taillifet D	2 - 185
3	Taira K	2 - 473
3	Talbott EO	2 - 461
1	Talbott EO	2 - 69
4	Tamalet D	2 - 527
4	Tarriere C	2 - 527
6	Tartoni P	2 - 593
5	Tassi P	1 - 54
4	Tassi P	2 - 519
3	Taylor R	2 - 469
1	Teyssou M	2 - 13
1	Teyssou M	2 - 79
6	Thibaud JP	2 - 419
5	Thomas C	2 - 563
8	Thomas M	2 - 311
3	Thompson SJ	1 - 22
2	Tohyama M	1 - 21
1	Touma JB	2 - 139
2	Tran Quoc H	2 - 169
8	Trimmel M	1 - 34
6	Turunen-Rise I	2 - 423
1	Vaccari V	2 - 109
opening	Vallet M	1 - 1
4	Vallet M	2 - 523
6	Vallet M	2 - 593
6	Vallet M	2 - 615
5	Van F	2 - 569
1	Van den Berg R	2 - 141
9	Van Den Berg M	1 - 14
5	Van F	1 - 49
1	Varao L	2 - 123
6	Veltman JA	2 - 429
8	Vernet I	2 - 273
6	Vernet I	2 - 389
2	Viljanen V	2 - 189
2	Vilkman E	2 - 177
6	Vincent B	2 - 425
9	Vogel A	1 - 15
9	Vogiatzis C	1 - 68
6	Vogiatzis C	2 - 615
9	Von Gierke HE	1 - 12
3	Voronin AN	2 - 501
6	Vos J	2 - 429
9	Wai CP	2 - 647
6	Walker JG	2 - 433
7	Wallace MC	1 - 28
9	Wallis AD	2 - 629
key note	Ward W	1 - 10
1	Ward WD	1 - 46
5	Watson A	1 - 49
5	Watson A	2 - 569
9	Watson I	2 - 451
7	Weiland LE	2 - 251
7	Weisenberger ME	1 - 28
1	West DW	2 - 101
1	Weston RJ	2 - 145
9	Weston RJ	2 - 455
7	White RG	1 - 29
6	Widmann U	2 - 201
7	Wisely S	1 - 27
6	Wolsink M	2 - 235
2	Woxen OJ	2 - 193
7	Woxen OJ	2 - 255
7	Wursig B	2 - 260
3	Yamamoto T	2 - 473
6	Yamashita T	2 - 197
6	Yamashita T	2 - 217
6	Yano T	2 - 197
6	Yano T	2 - 217
1	Ye Q	2 - 37
6	Yügrük N	2 - 619
8	Zeichart K	2 - 299
1	Zeidan J	2 - 21
3	Zhang S	1 - 25
7	Zhang S	2 - 261
3	Zhang S	2 - 493
8	Zhao C	2 - 317
3	Zhao Y	1 - 25
7	Zhao Y	2 - 261
8	Zhao Y	2 - 317
3	Zhao Y	2 - 493
1	Zhou SK	2 - 37
6	Zhukov AN	2 - 415